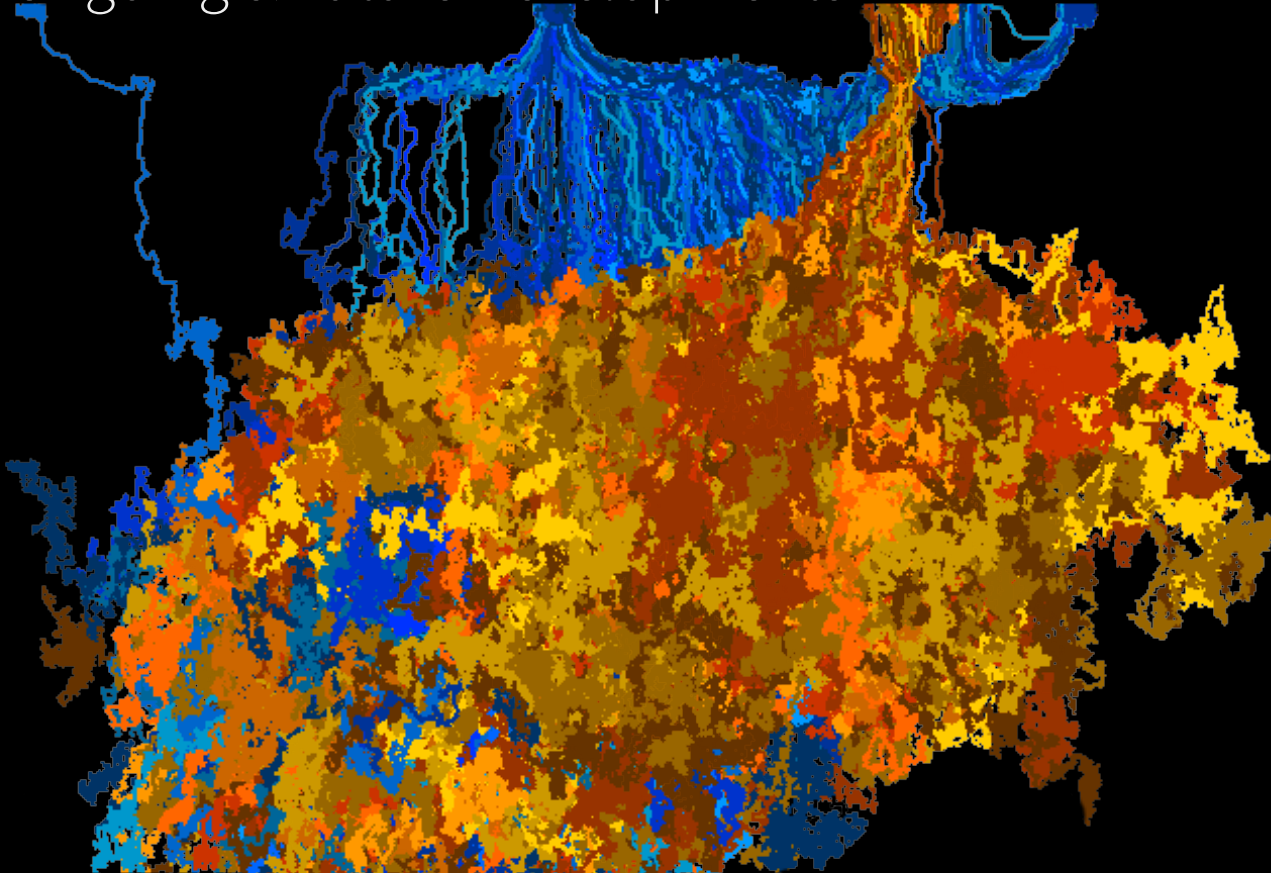




<https://www.desy.de/>

Allpix Squared z.y.x

Ongoing & Future Developments



Simon Spannagel, DESY
for the Allpix Squared Authors

5th Allpix Squared User Workshop
University of Oxford
24 May 2024

What to expect from these slides

- Wild collection of things that
 - Are prototype algorithms requiring validation
 - Are ongoing developments
 - Are fleshed out ideas awaiting implementation
 - Are rough ideas
- Overview of forming DRD3 WG4 (Simulations working group)
 - Input collected in last year's community event
 - Some dates & links

WIP: Meshed magnetic field #46

Edit <> Code

 Draft sam-sw wants to merge 9 commits into `allpix-squared:master` from `sam-sw:meshed-magnetic-field` 

Sam Wood

 Conversation 15  Commits 9  Checks 22  Files changed 4

+111 -21 



sam-sw commented on Mar 4 • edited

Contributor ...

Work-in-progress addition to the `MagneticFieldReader` module to allow loading from mesh files, much like in the `ElectricFieldReader` case.

Currently working:

- Loading a set of B-field 3-vectors from a file
- Making sure GEANT4 reacts to the non-constant field across the world volume
- Fallback config option for a constant field outside the specified mesh volume (defaults to 0T)

Still to do:

- Config option to specify the volume centre (currently defaults to centring the mesh about the origin)
- Config option to specify volume start (e.g. pinning bottom-left corner of mesh to a coordinate, rather than centring the mesh about a location).
- Create output plots of loaded field
- Documentation and tests

Very happy to receive comments and suggestions on the current implementation!



Reviewers

 **simonspa**  

Assignees

No one—[assign yourself](#)

Labels

None yet

Projects

None yet

Milestone

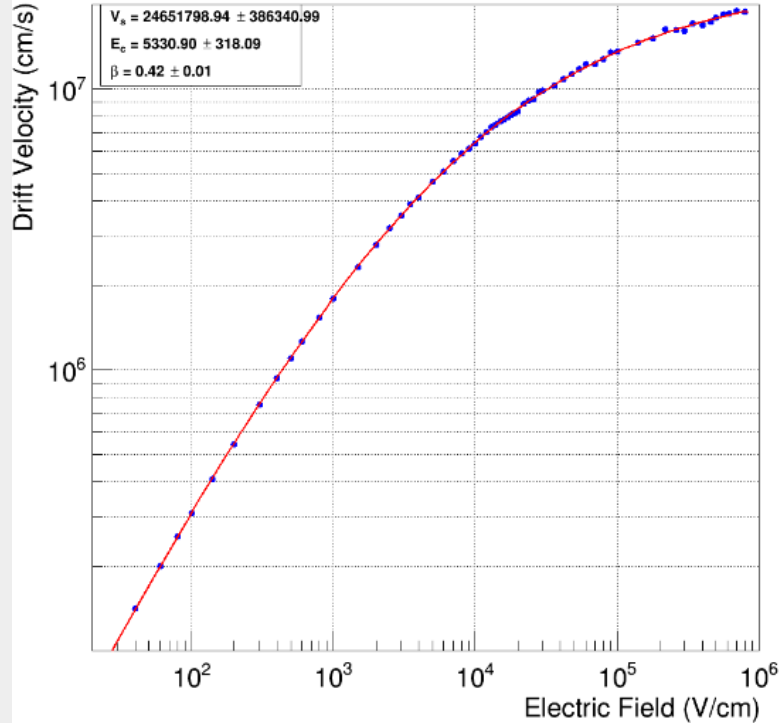
No milestone

Development

Successfully merging this pull request may close these issues.

None yet

Diamond-Electron Drift Velocity vs Electric Field at 300K

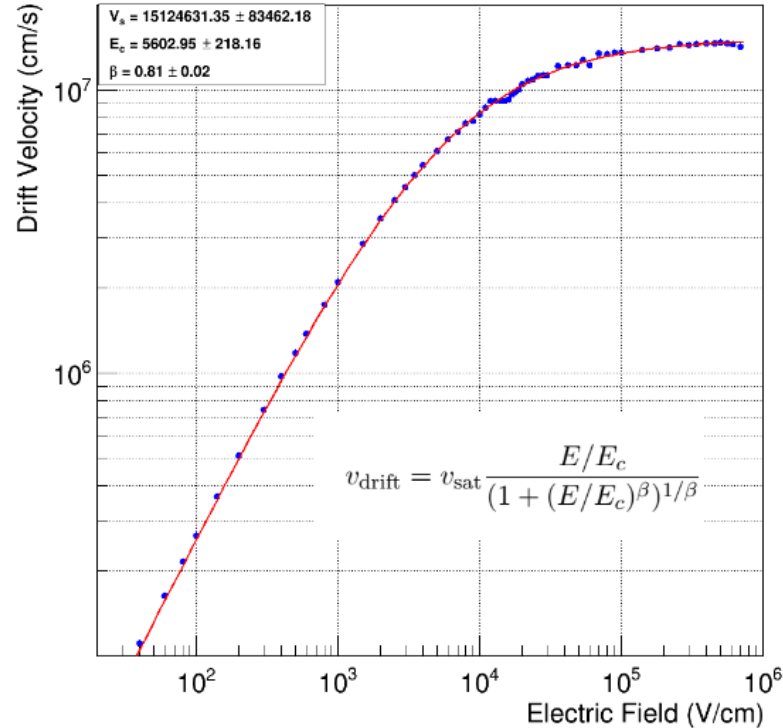


Values in Literature

- $V_s = 2.63 \times 10^7 \pm 0.2 \times 10^7 \text{ cm/s}$
- $E_c = 5779 \pm 772$
- $\beta = 0.42 \pm 0.01$

<https://doi.org/10.1002/pssa.201532230>

Diamond-Hole Drift Velocity vs Electric Field at 300K



Values in Literature

- $V_s = 1.57 \times 10^7 \pm 0.14 \times 10^7 \text{ cm/s}$
- $E_c = 5697 \pm 529$
- $\beta = 0.81 \pm 0.01$

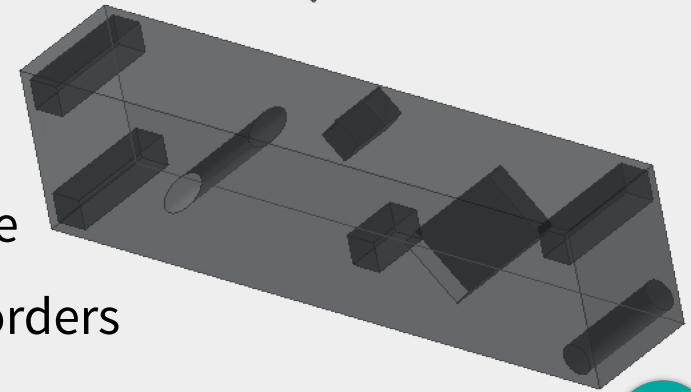
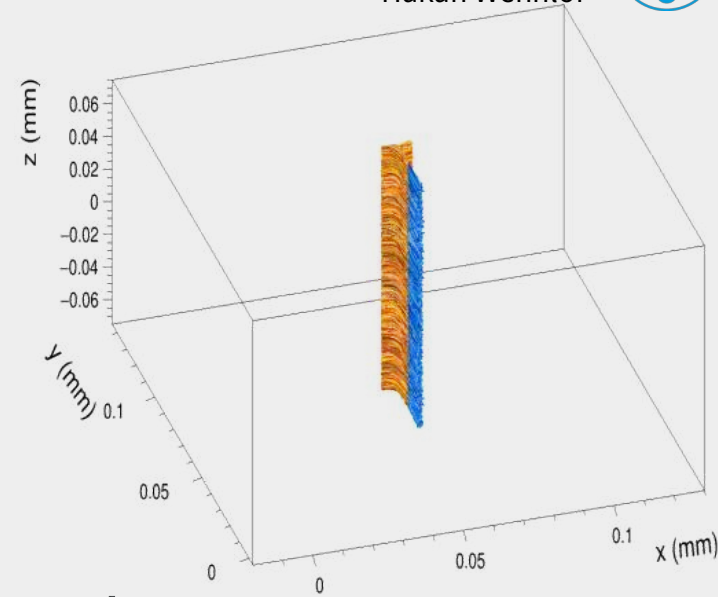
<https://doi.org/10.1002/pssa.201532230>

Improve 3D Sensor Simulations

Jixing Ye,
Håkan Wennlöf



- 3D sensors available since APSQ 3.0
 - Elliptical or rectangular implants
 - Frontside, backside
- Still some things to improve for different applications
- More implant shapes, combine shapes as unions
- Currently only silicon as filler material
Sensor is solid block in Geant4
- Other materials e.g. trenches w/ Li6 for neutron capture
- Ironing out some boundary condition issues at pixel borders



Further Improvements on Impact Ionization



- Impact ionization notoriously difficult to simulate
 - Strong effect with potential for avalanche generation / divergence
 - Often limited to very small volumes
 - Field used for per-step local gain determination: $(E_{pre} + E_{post})/2$
 - LGADs: high electric field slopes at the borders of the gain layer
 - Propagation steps into and out of gain layer lack precision due to non-linear dependency of gain on electric field
 - Reduction in step size would apply to entire sensor → time consuming
 - Several ideas for improvements: in case of large field differences, ...
 - Calculate position of threshold (or 50%) field and scale gain, e.g. via binary search, see [!1000](#)
 - Perform sub-sampling and integration of gain
- Regular stepping
 - When encountering step from field < threshold to field > threshold: subsample
 - Find position along step with field = threshold
 - Scale applied gain coefficient with distance



Native Support for Simple LGAD Fields



- Adding an option that does not require TCAD simulations for simple gain layers

```
/**  
 * @brief Different electric field types  
 */  
enum class ElectricField {  
    CONSTANT, ///  
    LINEAR, ///  
    MESH, ///  
    PARABOLIC, ///  
    GAINLAYER, ///  
    CUSTOM, ///  
};
```

- In principle already possible, e.g. via

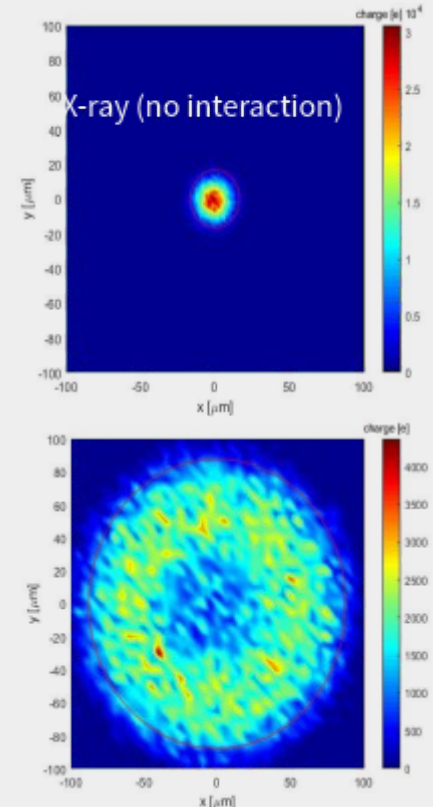
```
[ElectricFieldReader]  
model = "custom"  
field_function = "((z < [0]) ? [3] : ((z > [1]) ? [3] : [2]))"  
field_parameters = 23um, 24.5um, -320kV/cm, -5000V/cm
```

- Easier for end-users to provide directly as field type, first works done in student project, see [!1069](#)



High Charge Density Effects

- Current MC simulation modules based on simplification:
No interaction between charge carriers
 - Very good approximation for low charge densities
 - Very fast since carriers can be transported individually
- Breaks down with high charge densities:
we need Coulomb field contribution to external field
 - Many applications (X-ray imaging/diffraction, Alpha measurements, UCN imaging, anti proton annihilation, ...)
- Work ongoing on new propagation module including interaction between charge carriers
- Still early state, investigating possibilities for reducing computational load

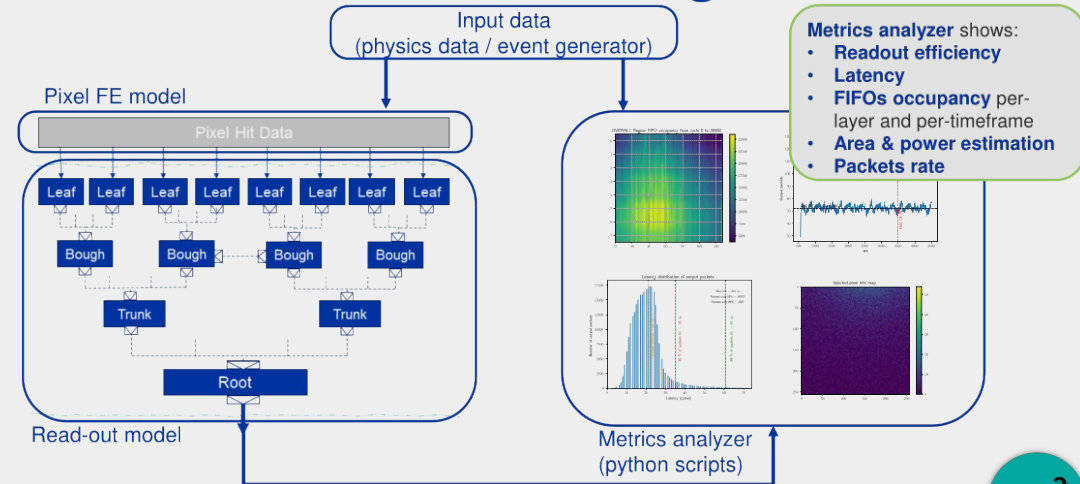


Simulating Readout Architectures



- Would be interesting to study impact of readout system architecture on chip performance (Data buffers, readout bandwidth, ...)
- Could investigate simplified implementation in Allpix Squared – sequential module with local event buffers, possibility to define readout paths
- Or: provide interface to electronics-level simulations
- PixESL: “Electronic System Level prototyping framework for architecture modeling of future particle detectors”

PixESL – Framework Diagram





Integration with Circuit Simulations

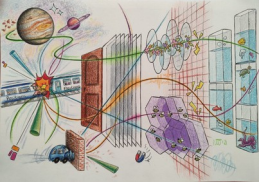
- Front-end simulations in Allpix Squared are relatively simple
 - DefaultDigitizer – just applies threshold
 - CSADigitizer – allows usage of transfer function to fold signal
- Transfer function still needs to be calculated externally, e.g. using LTSPICE, Cadence Virtuoso, ...
- Possible developments towards providing an interface
 - Export of e.g. pulse information towards circuit simulators
 - Import of transfer functions or simulation models



Allpix Squared & DRD3

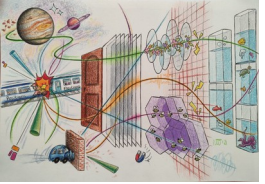
Development Goals & Milestones by the Community





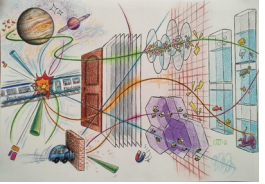
Semiconductor Detector MC Simulations DRD3

- Complexity of detectors increases, more and more technologies available, different approaches combined (e.g. monolithic + LGAD)
 - Necessity of MC simulations growing
 - Some sensors / setups impractical to simulate in TCAD (time limitation, stochastics)
 - Community needs *common* flexible, tested & supported MC simulation tools
- Using Monte Carlo methods to describe detector response is not new
- Creation & proliferation of many different codes for detector simulation
 - Experiment-specific
 - Specialized on specific detectors
 - Inclusion only of effects relevant to that one simulation
 - Written as part of a PhD thesis, abandoned afterwards
- Would be great to collate features in commonly maintained software (->SM)
 - Having several tools is valuable as testbed for algorithms
 - Well-maintained & supported common software will significantly ease use in community



Future Directions & Developments DRD3

- **Development & extension of common Monte Carlo tools**
 - Continue development of flexible, universal framework for semiconductor MC simulations
 - Validation of algorithms / models
- **Model building for adaptive electric fields**
 - LGADs - gain screening
 - Plasma effects - high local charge densities, heavy ions, high gamma fluxes
 - Dynamic trapping/de-trapping models
- **Time-weighted simulation approach - dynamic weighting field**
- **Development of commonly-used front-end circuit models**
 - Hit digitization modeling, possibility of tuning towards specific applications
 - Interface to SPICE simulators
- **Continue documentation & training effort**
 - User workshops & tutorials / trainings
 - Providing reference manual with models, simulation flow description, ...



Milestones, Deliverables & Resources DRD3

Short term (S-) / mid term (M-) milestones (-M) and deliverables (-D):

- SM - Validate current impact ionization modeling
- SD - Develop algorithm to include adaptive e-fields (brute-force)
- SM - Collate solutions from different MC tools
- MM/D - Investigate possible ways to simulate front-end responses
- MD - Pre-defined digitization models for different devices / front-ends

Long term (L-)

- LD - Build model to approximate space charge effects (computat. efficient)

Resources

- Model building requires dedicated resources
 - Should take into account that model validation requires (pre-analyzed!) data
- Support, training, dissemination requires dedicated resources
 - Should investigate if sensible to combine with TCAD training
- Estimate of ~ 5 FTE for MC simulation tools development & training

Allpix Squared & DRD3 WG4

- WG 4 Simulations
<https://drd3.web.cern.ch/wg4>
- Preparatory Meeting (online), 03/06/2024, 10:00 CEST
<https://indico.cern.ch/event/1413316/>
- Expressions of Interest
<https://cernbox.cern.ch/files/link/public/QcJZDNdHNzctjNx/WG4-simulation>
- 1st DRD3 Week 17-21/06/2024
<https://indico.cern.ch/event/1402825/>

Summary

and Weather Forecast

Summary

- APSQ development relies on active participation in development
 - Small core developer team which lacks resources to implement wishes
 - More importantly that lacks the resources to check & validate the algorithms!
- Many interesting areas of future developments identified
- Some features already in development
- Expecting influx of interested parties from DRD3 WG4 community
- Looking forward to an interesting year of new developments

...see you at the the 6th Allpix Squared User Workshop in ...?

Today

16° 9°

Sunrise:
05:00

Sunset:
21:05

Cloudy changing to sunny intervals
by early evening.



UV



Pollution

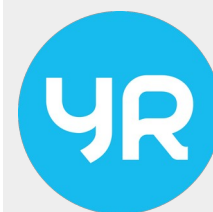


Pollen

Sat 25 May	Sun 26 May	Mon 27 May	Tue 28 May
20° 12°	18° 10°	16° 10°	16° 10°

Today												
11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Chance of precipitation i												
10%	10%	<5%	10%	10%	<5%	<5%	40%	<5%	<5%	<5%	<5%	<5%
Temperature °C v i												
13°	13°	14°	15°	16°	16°	16°	15°	15°	15°	13°	12°	12°

Today 24 May



Time	Weather	Temp.	Precip. mm	Wind speed m/s	Wind desc.
10		13°		3 ↗	Light breeze from south west
11		14°		3 ↗	Light breeze from south west
12		14°		3 ↗	Light breeze from south west
13		15°		3 ↗	Light breeze from west
14		15°		4 ↗	Gentle breeze from south west
15		16°		4 ↗	Gentle breeze from south west
16		16°		3 ↗	Light breeze from west
17		16°		2 ↗	Light breeze from south west
18		16°		2 ↗	Light breeze from south west
19		15°		2 ↗	Light breeze from south west
20		14°		1 ↑	Light air from south
21		14°		2 ↑	Light breeze from south
22		13°		2 ↑	Light breeze from south
23		12°		2 ↗	Light breeze from west





Allpix Squared Resources



Website

<https://cern.ch/allpix-squared>



Repository

<https://gitlab.cern.ch/allpix-squared/allpix-squared>



Docker Images

https://gitlab.cern.ch/allpix-squared/allpix-squared/container_registry



User Forum:

<https://cern.ch/allpix-squared-forum/>



Mailing Lists:

allpix-squared-users <https://e-groups.cern.ch/e-groups/Egroup.do?egroupId=10262858>

allpix-squared-developers <https://e-groups.cern.ch/e-groups/Egroup.do?egroupId=10273730>



User Manual:

<https://cern.ch/allpix-squared/usermanual/allpix-manual.pdf>

