Updates on Allpix Squared
Two Years of Experience, Development, Improvements

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“Allpix\textsuperscript{2} is a generic, open-source software framework for the simulation of silicon pixel detectors. Its goal is to ease the implementation of detailed simulations for both single detectors and more complex setups such as beam telescopes from incident radiation to the digitised detector response.”

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...okay, Two Slides

- Separate infrastructure (core) from the physics (modules)
- Make life easy:
  - Allow plugging together the simulation chain from individual modules
  - Auto-generate Geant4 models
  - Convenient configuration, with units
  - Offer a selection of different algorithms
  - Possibility to integrate TCAD electric fields
- A variety of installation methods...
Allpix² – Users & Contributors

Disclaimer: these are just some users we have been in contact with – there probably are some more.

- ONERA Aerospace Lab, Toulouse
- Georg-August-Universität Göttingen
- University of Birmingham
- University of California, Berkeley
- NIKHEF, Amsterdam
- University of Glasgow
- Czech Techn. University, Prague
- Rutherford Lab, STFC
- ETH Zurich
- Université de Montréal
- Charles University, Prague
- IHEP Beijing
- Freiburg University
- Utrecht University
- Université de Genève
- AGH University Krakau
- ATLAS @ DESY
- CMS Lorentz Angle @ DESY
- ELAD @ DESY
- University of Liverpool
- ATLAS SCT @ KEK
- Dortmund University
- Université de Genève

- First **user workshop** held
  - 26-27 November 2018 @ CERN
- Tutorials, discussions, feedback
- Very successful, to be continued
- We have a **forum** now!
Installation on CVMFS – CernVM File System

“provides a scalable, reliable and low-maintenance software distribution service. It was developed to assist High Energy Physics (HEP) collaborations to deploy software on the worldwide-distributed computing infrastructure used to run data processing applications”

https://cernvm.cern.ch/portal/filesystem

- Central installation of software for SLC6 and CC7
- Using project space of CLICdp at /cvmfs/clicdp.cern.ch/software/allpix-squared/
- Load all dependencies, C++ libraries & set up $PATH using setup.sh file:

```
$ source /cvmfs/clicdp.cern.ch/software/allpix-squared/1.3.1/x86_64-centos7-gcc7-opt/setup.sh
$ allpix --version
Allpix Squared version v1.3.1
built on 2018-12-17, 09:59:00 UTC
```
“Docker is a computer program that performs operating-system-level virtualization, also known as containerization”

https://en.wikipedia.org/wiki/Docker_(software)

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

- Start an interactive shell inside the Docker:

```
$ docker run --interactive --tty
   --volume "$(pwd)":/data
   --name=allpix-squared
   gitlab-registry.cern.ch/allpix-squared/allpix-squared:v1.3.1
   bash
```

- Directly start a simulation:

```
$ docker run --tty --rm
   --volume "$(pwd)":/data
   --name=allpix-squared
   gitlab-registry.cern.ch/allpix-squared/allpix-squared:v1.3.1
   "allpix-c my_simulation.conf"
```

Cheat Sheet:

- **--tty** Allocate a pseudo-TTY
- **--rm** Automatically remove container when it exits
- **--interactive** Keep STDIN open even if not attached
- **--volume** Bind mount a volume
- **--name** Assign a name to the container
Okay, I know this from last year. What’s new, really?
Magnetic Fields & Lorentz Drift

- Implemented by Paul Schütze, DESY
- New module to read global magnetic fields – currently: const.
- Lorentz Drift – deflection of charge carriers in motion

```python
[MagneticFieldReader]
model = "const"
magnetic_field = 0mT 3.8T 0T
```
Magnetic Fields & Lorentz Drift: Example

- Simulate measurement of Lorentz Angle in silicon detectors (Paul Schütze)
  - Rotation of detector om magnetic field
  - Determine minimal cluster size to obtain Lorentz angle
Electric Field: Scaling & Shifting

- Allows the usage of different electric field map sizes, e.g.
  - Only simulate a quarter of a pixel unit cell in TCAD
  - Simulate multiple pixels to account for even/odd column differences
- Example (via Anastasiia Velyka, DESY) – shown is always a single pixel in AP2:

![Electric field plots](image-url)
Particle Source Shapes & Radioactive Decays

- Different shapes: implemented by Thomas Billoud, U Montreal
  - Not only allow beam-shaped sources but also
    - Point sources
    - Spheres – “particles from all directions” (measurements in outer space)
    - Square
  - Possibility to feed G4 macro to define custom source parameters

- Allow simulation of radioactive decays via Geant4
  - Decay chain is interrupted after primary decay
  - Isotopes implemented: Fe55, Am241, Sr90, Co60, Cs137.
Google Summer of Code

- Google is funding students to work on open-source projects
  - Student applied to project: solving initial tasks, writing proposal
  - Accepted student works on project for 12 weeks
  - Regular evaluations, if positive, Google pays out scholarship

- We have mentored a GSoC student in 2018 through HSF/CERN
  - Proposed project: Event-based Multi-Threading for Allpix Squared
  - Quite intricate due to seeding of PRNGs & potential race conditions
Google Summer of Code

- GSoC student: Viktor Sonesten, U Luleå
  - Restructured parts of core framework, implemented first working version
  - Took care of module thread safety, seed distribution, relaying messages, logging...
- Some problems arose…
  - Issue with ROOT’s Tref objects
    - Reported upstream, fixed
  - Complications with Geant4’s interface & multi-threading
    - To be worked on
  - Not yet ready for prime-time
Okay, sounds nice.
But does it actually work?
Simulation of a Timepix3 with 50um Planar Sensor

- Full telescope: 6 planes Timepix3 + DUT
- Linear electric fields
- Full reconstruction: clustering, eta correction, tracking

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Monolithic CMOS in High-Resistivity Silicon

- Simulation of ALICE Investigator-like chip, 28x28um pitch
  - Field in top 25um (high-resistivity) silicon
  - Undepleted in 75um silicon substrate
- SPS beam: 120 GeV Pions, only DUT simulated
  - Using Monte Carlo truth information as reference
  - Smeared with telescope resolution obtained from data
- Import electric field from TCAD simulations
- Using Geant4’s photoabsorption Ionization model (PAI) for thin sensors
- Challenges: life time / recombination, influence of charge cloud on field…
  - Trade-off between accuracy and necessary simplifications
Monolithic CMOS in High-Resistivity Silicon

- Manage to reproduce x-y-correlation features in cluster size
- Data and simulation matches very well: **cluster size & resolution vs. threshold**
- Comparison: linear field simulation does not describe data

**CLICdp work in progress**
Summary

- “Allpix Squared: framework for the simulation of silicon pixel detectors”
- Continuously developed and extended
- New features in 2018:
  - Magnetic Fields, more flexible electric fields, particle sources
  - Participated in GSoC: Multi-threading
- Working on more applications of the software: CMOS sensors, CLICdp prototypes
- Plans for 2019:
  - Get you involved
  - Try to mediate between many ideas and limited time to implement them
    (transient current, high-Z materials, multi-threading, charge multiplication, lifetime)
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:
Okay.
How can I contribute?
Workflow for Code Contributions

- Discuss (forum, mailing list, issue tracker, in person)
- Fork the repository
- Alter the code
- Discuss, ask questions, follow coding style
- Create merge request against main repository
- Discuss, allow for code review
- Implement requested changes
- Discuss again
- Whoop with glee when your code gets merged