http://clicdp.cern.ch

Allpix Squared: Status & Plans

Two Years of Experience, Development, Improvements

Simon Spannagel, CERN

CLIC Workshop

CERN, 21 – 25 January 2019

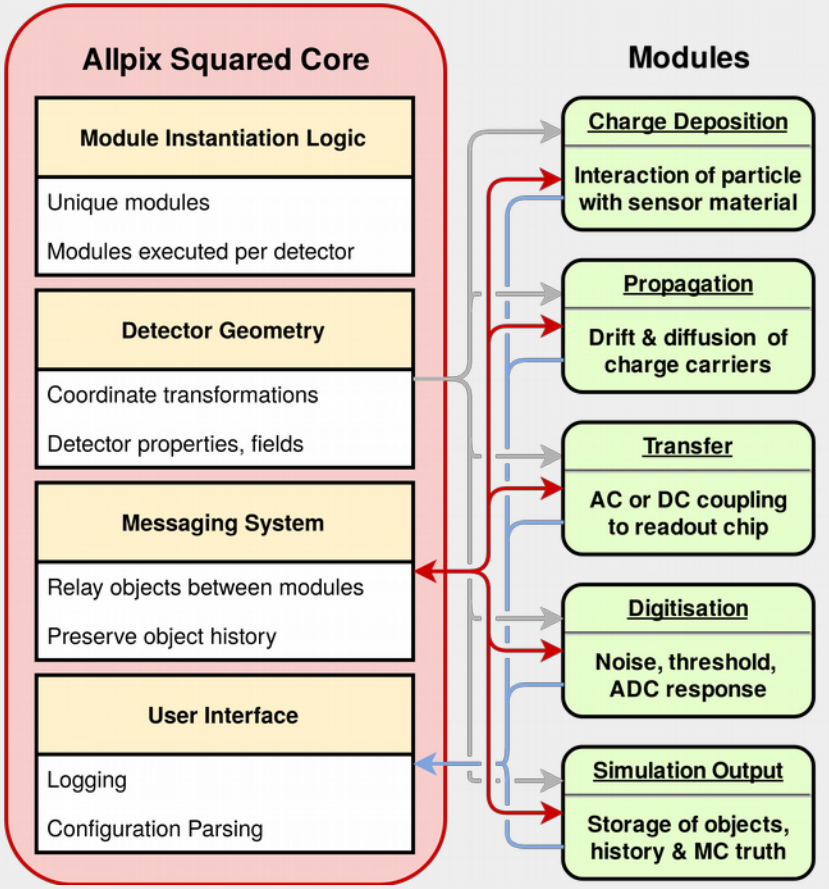
Allpix Squared on One Slide

"Allpix^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."

Nucl. Instr. Meth. A 901 (2018) 164 – 172
doi:10.1016/j.nima.2018.06.020

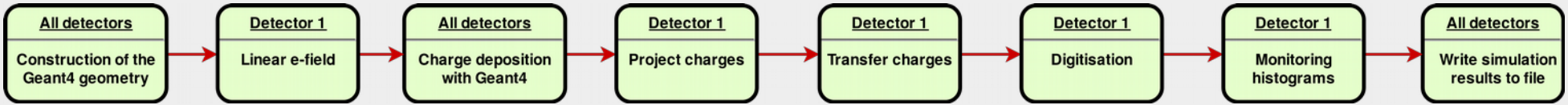
...okay, Two Slides

- 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...



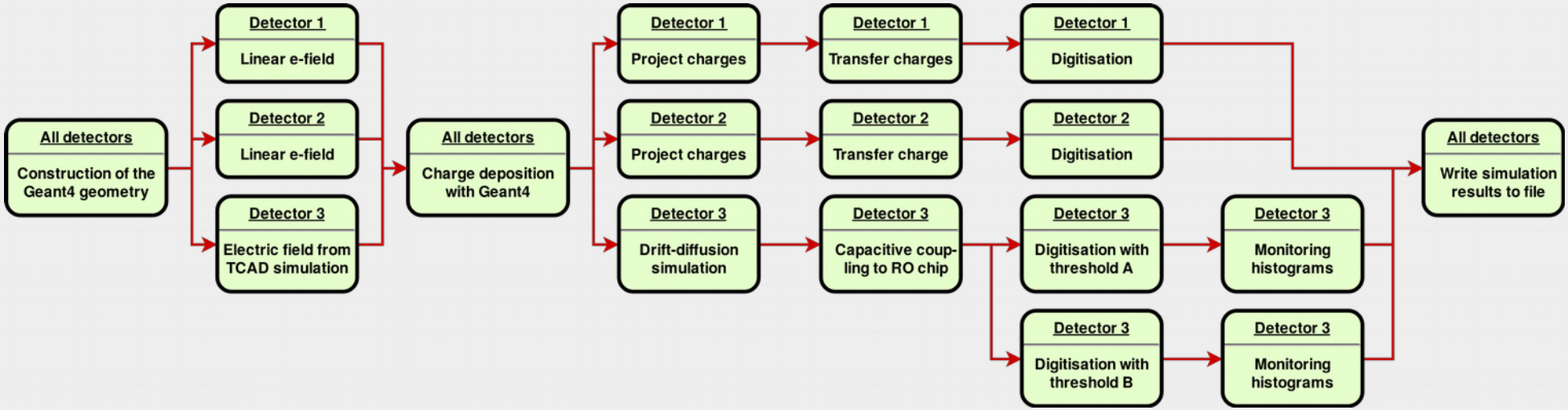
Simulation Chain

- Allows to quickly plug together simple simulations...
  (start from examples shipped in the repository)



Simulation Chain

- ...as well as more involved simulations



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
CLICdp @ CERN
CMS Pixel @ CERN
ATLAS Strips @ CERN
LHCb VeloPix @ CERN
ATLAS Monolithic @ CERN
ATLAS @ DESY
CMS Lorentz Angle @ DESY
ELAD @ DESY
University of Liverpool
ATLAS SCT @ KEK
Dortmund University
Université de Genève
AGH University Krakau

- 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

Continuous Improvements

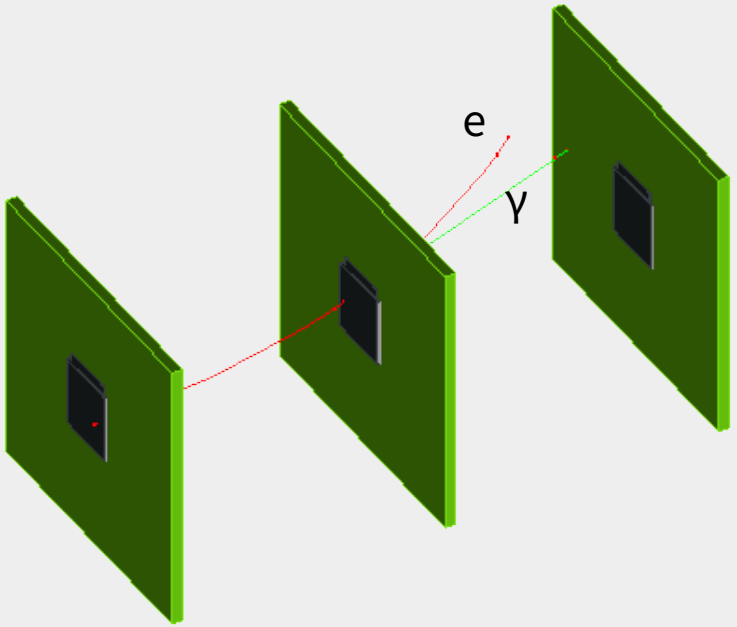
- Regular releases – 9 versions since last year

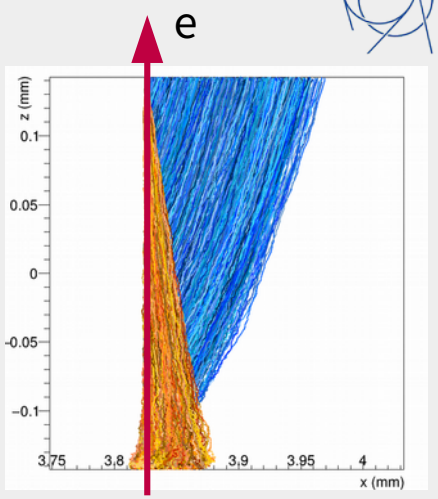
- Following semantic versioning
  - Major releases for structural changes
  - Minor versions for new features
  - Patch versions for bug fixes only

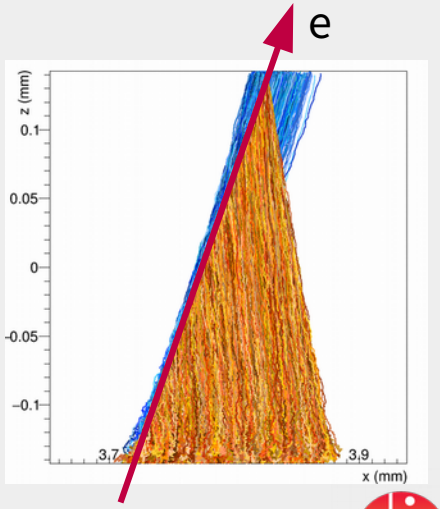
v1.3.1	2018-12-17
v1.3	2018-11-21
v1.2.3	2018-11-13
v1.2.2	2018-09-07
v1.2.1	2018-08-02
v1.2	2018-06-13
v1.1.2	2018-04-25
v1.1.1	2018-03-08
v1.1	2018-01-11
v1.0	2017-08-29

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



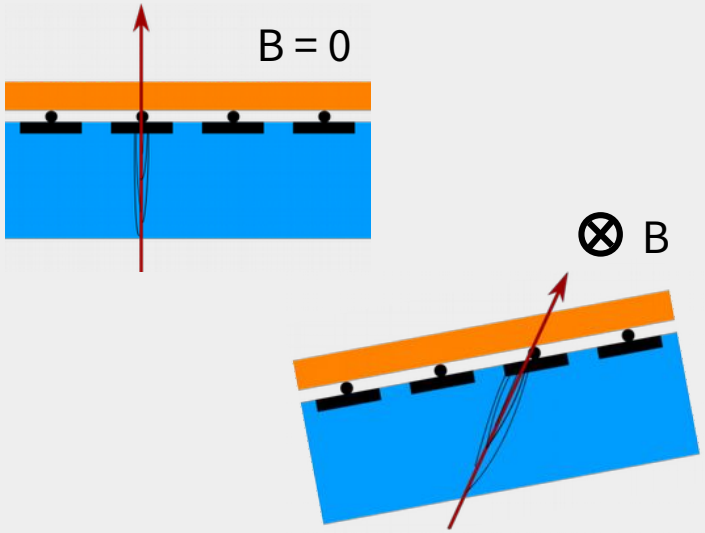




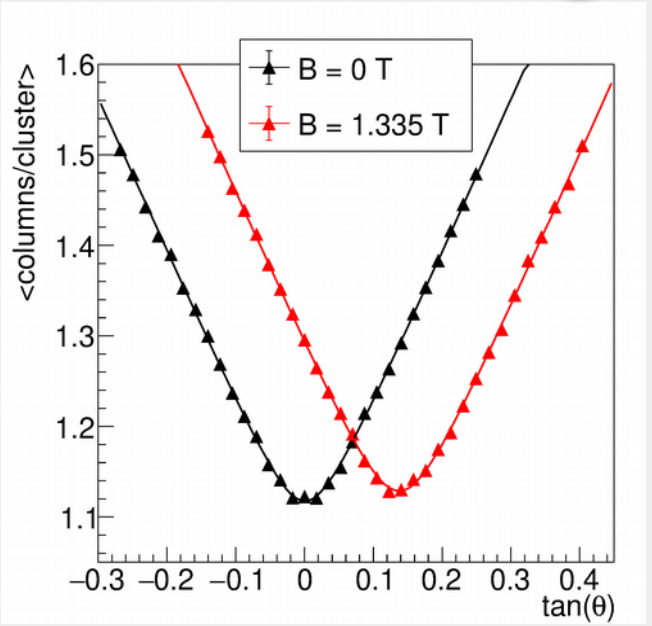

```
[MagneticFieldReader]
model = "const"
magnetic_field = 0mT 3.8T 0T
```

Magnetic Fields & Lorentz Drift: Example

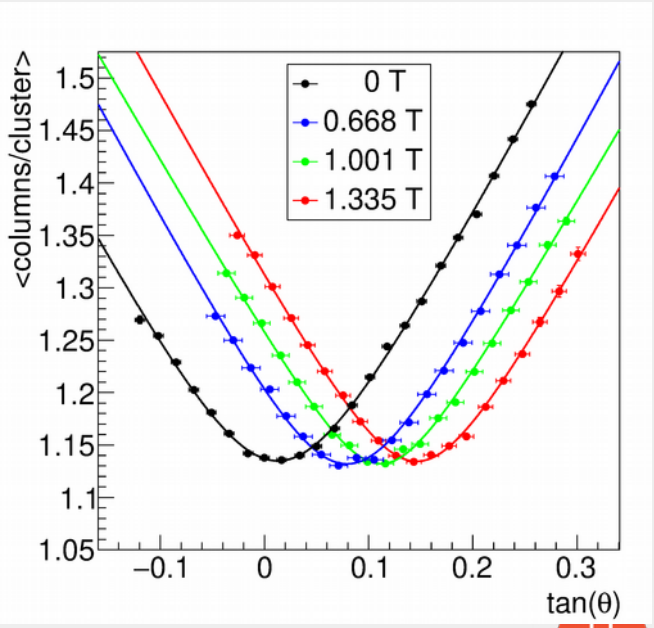
- Simulate measurement of Lorentz Angle in silicon detectors (Paul Schütze)
  - Rotation of detector om magnetic field
  - Determine minimal cluster size to obtain Lorentz angle



Simulation



Data

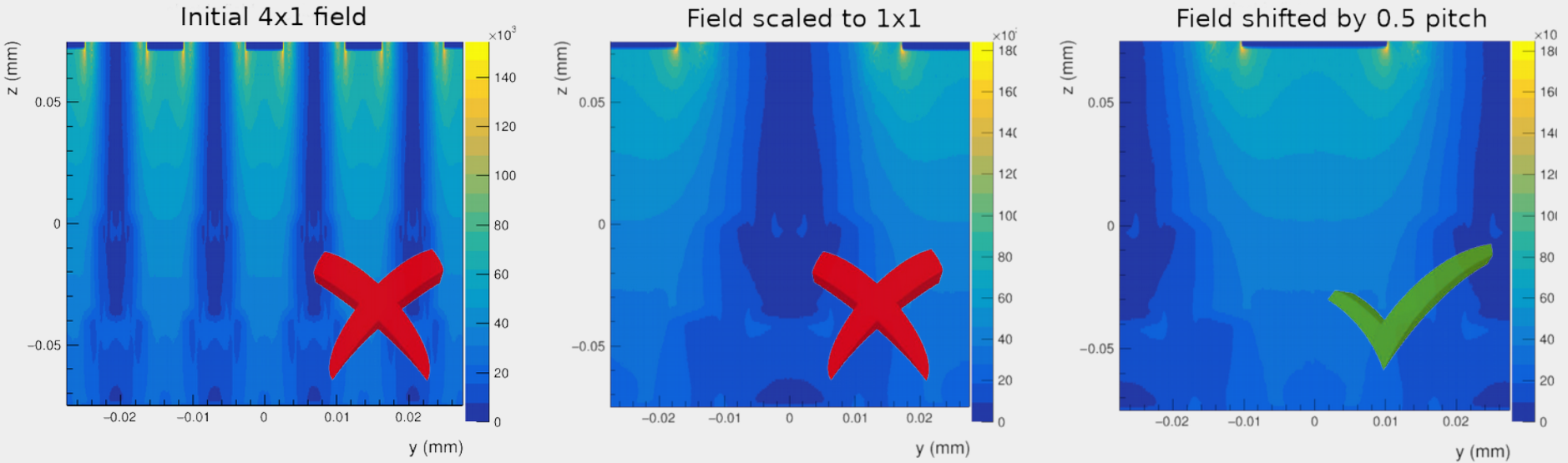


Electric Field: Scaling & Shifting

- 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

```
[ElectricFieldReader]
model = "init"
field_scale = 4.0 1.0
field_offset = 0.5 0.0
```

- Example (via Anastasiia Velyka, DESY) – shown is always a single pixel in AP2:



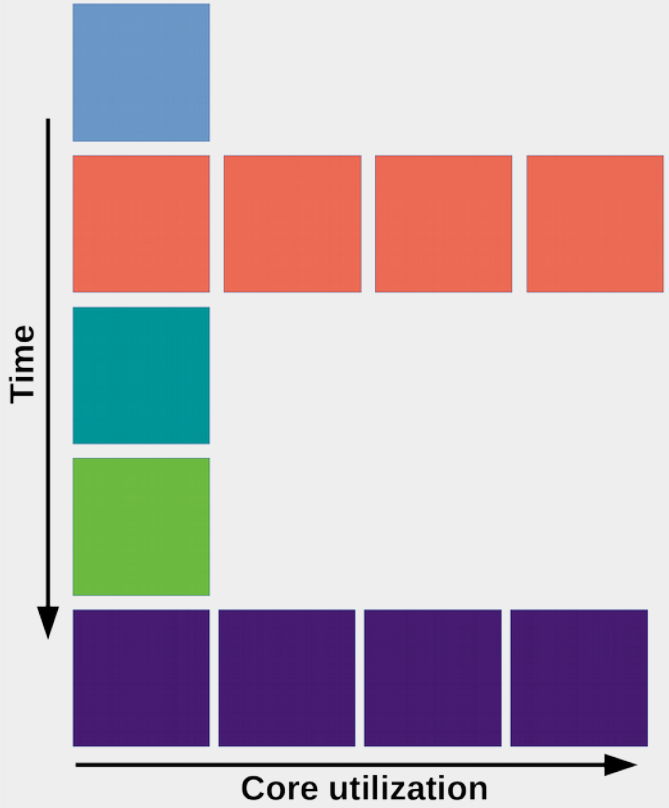
Google Summer of Code

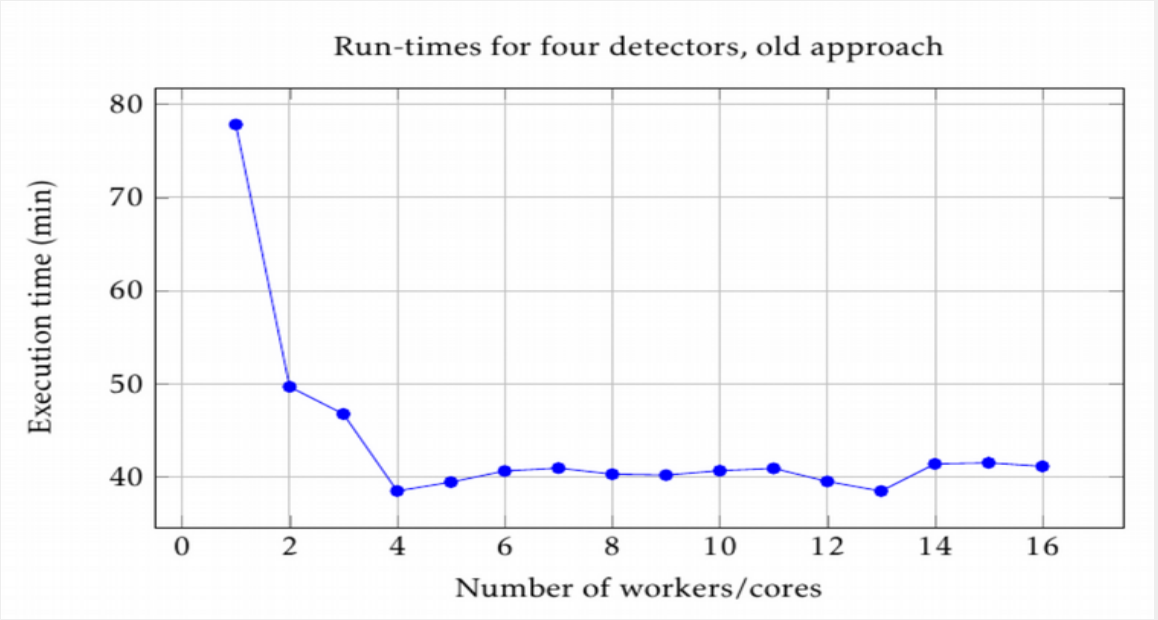
- Google is funding students to work on open-source projects
  - Student applied to project & writes proposal; accepted student has 12 weeks
  - Regular evaluations, if positive, Google pays out scholarship
- We have mentored a GSoC student in 2018 through HSF/CERN
  - Proposed project: Event-based Multi-Threading for Allpix Squared
  - Quite intricate due to seeding of PRNGs & potential race conditions

- 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...

Multi-Threading: now

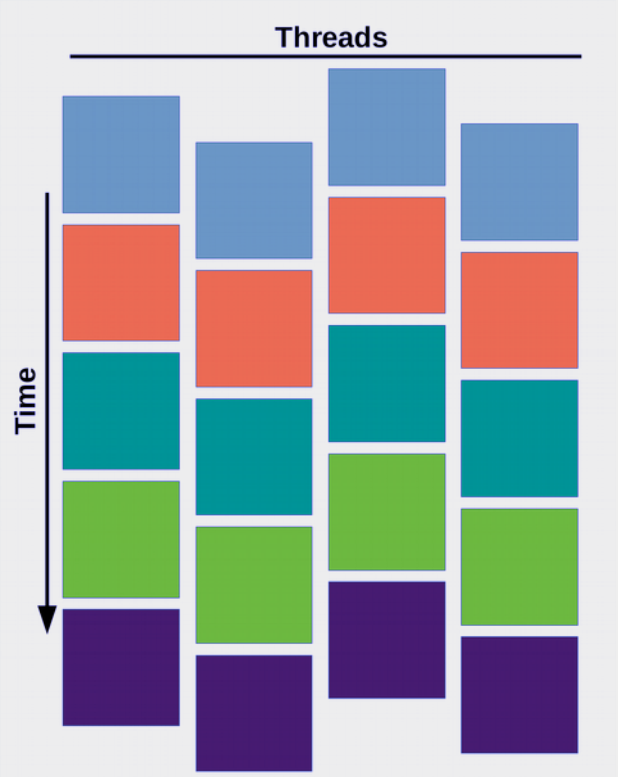
- Some individual modules parallelize individual detectors

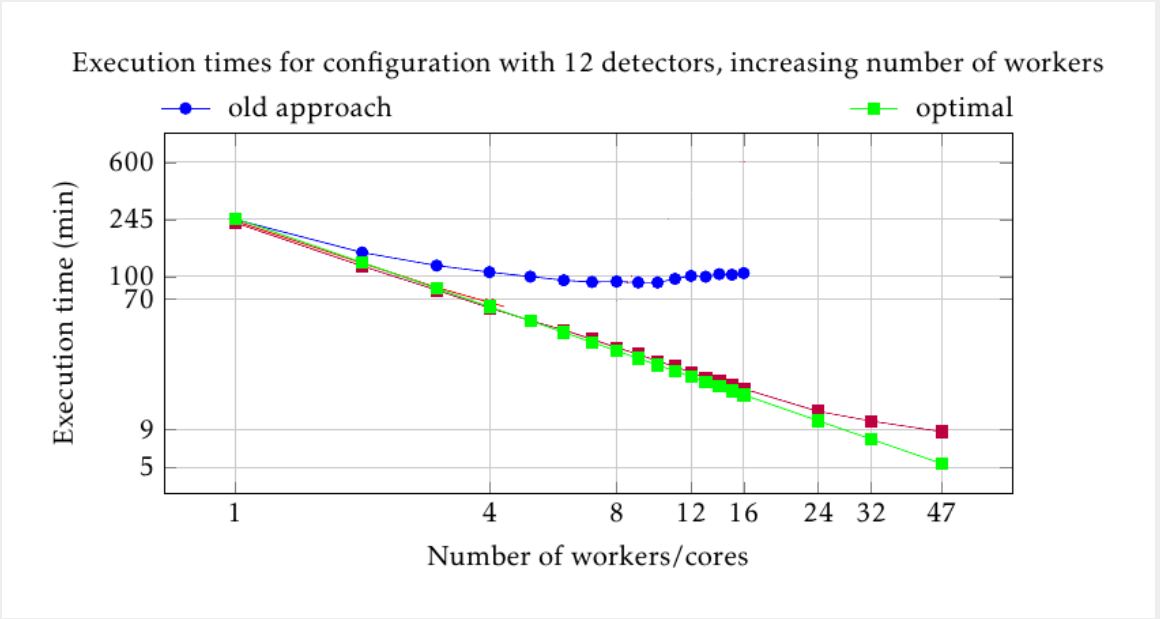




Multi-Threading: then

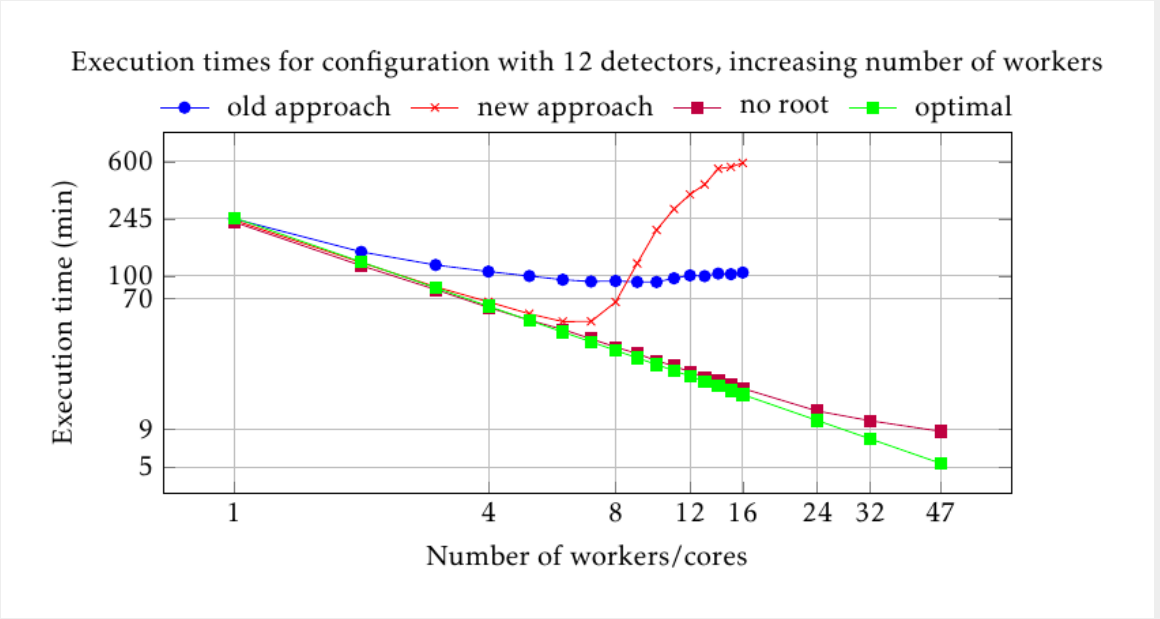
- Run individual events in parallel





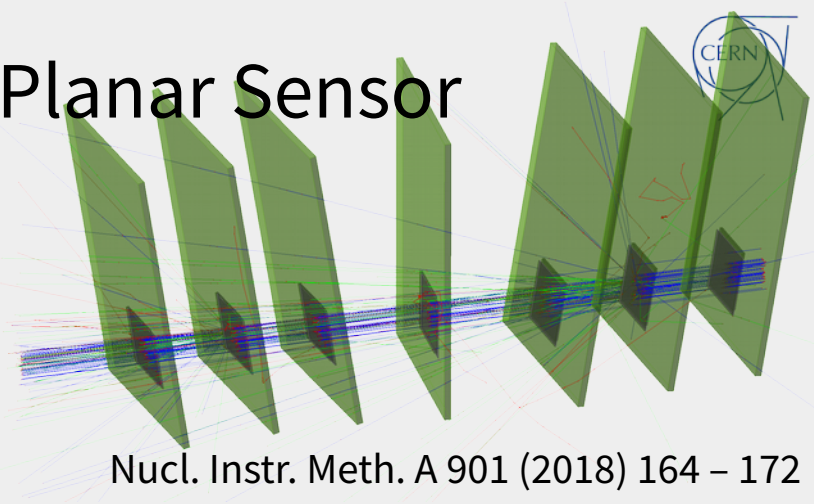
Google Summer of Code

- Some problems arose…
- Issue with ROOT's Tref objects
  - Reported upstream, fixed
  - Fix needs to be validated
- Complications with Geant4's interface & multi-threading
  - G4 does its own MT
  - Requires own run manager
  - To be worked on
- New MT not yet ready for prime-time



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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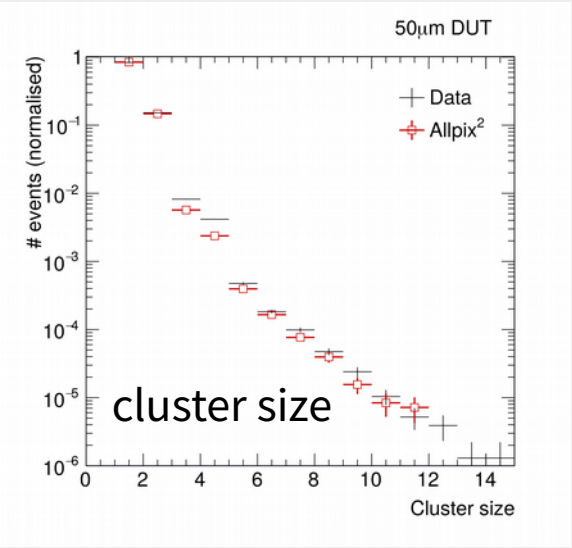
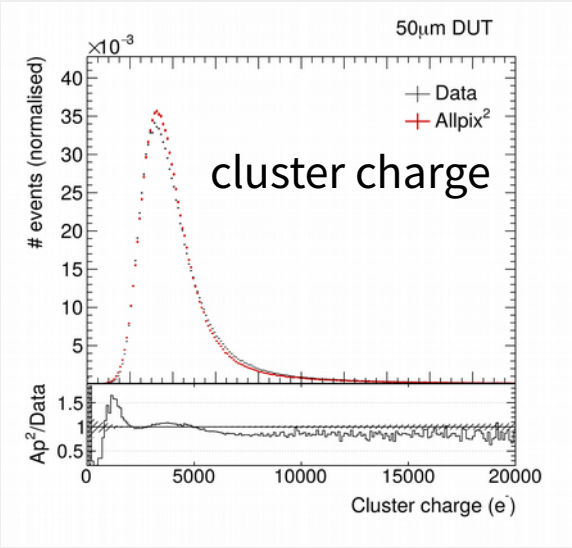
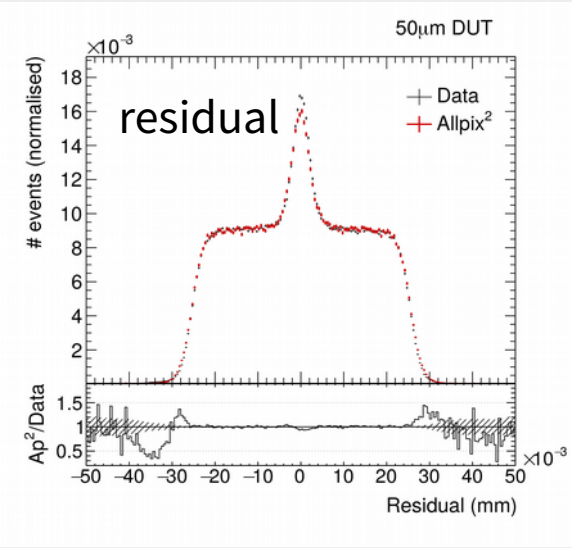
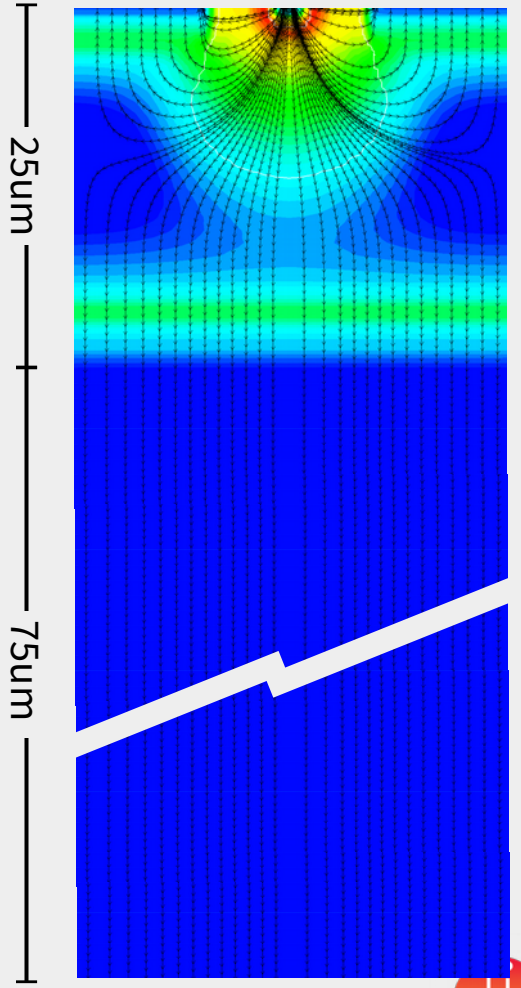






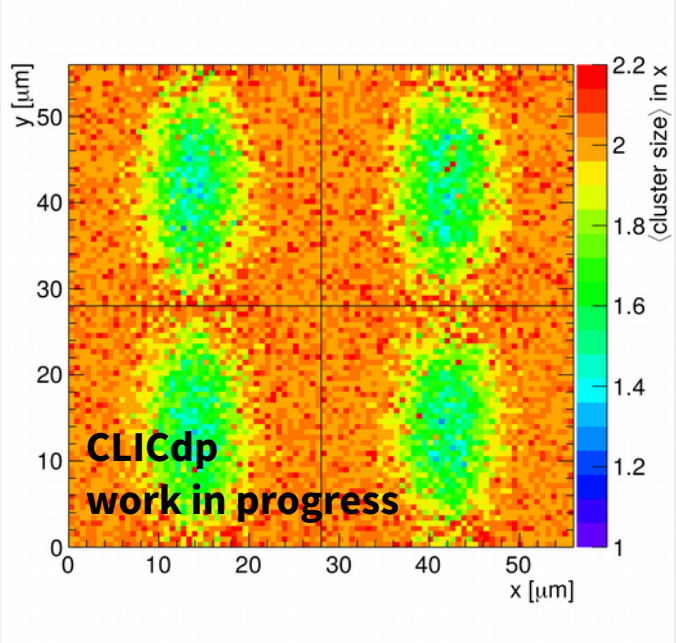
Monolithic CMOS in High-Resistivity Silicon

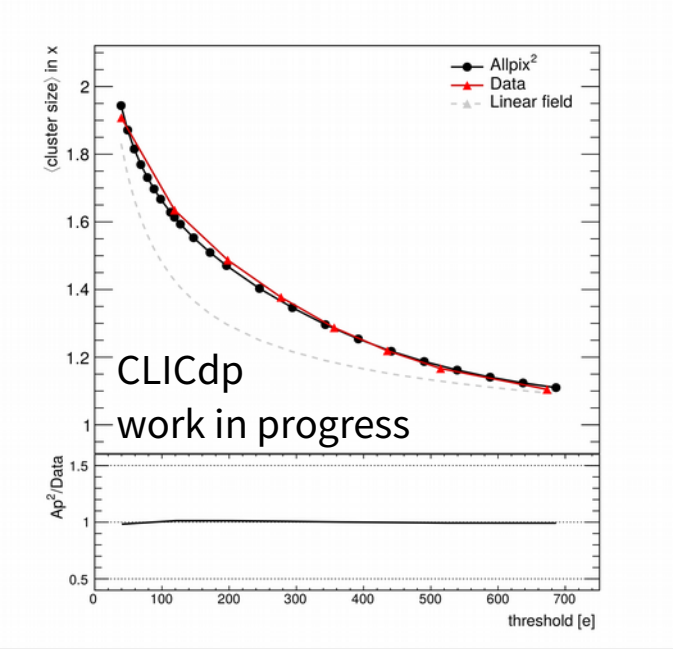
- Simulation of ALICE Investigator-like chip, 28x28um pitch
  - Field in top 25um (high-resistivity) silicon
  - Undepleted in 75um silicon substrate
- SPS beam: 120 GeV Pions, only DUT simulated
  - Using Monte Carlo truth information as reference
  - Smeared with telescope resolution obtained from 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

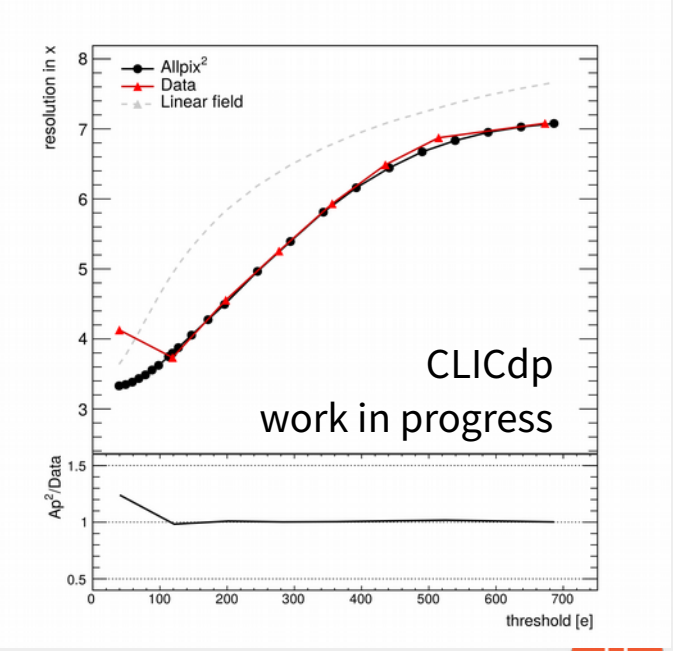


Monolithic CMOS in High-Resistivity Silicon

- 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







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 simulations: CMOS sensors, CLICdp protptypes

- Many ideas for extensions
  (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:

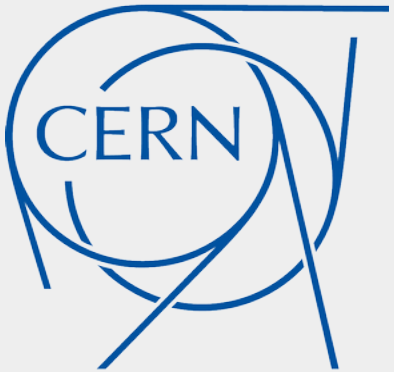
https://cern.ch/allpix-squared-forum/

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

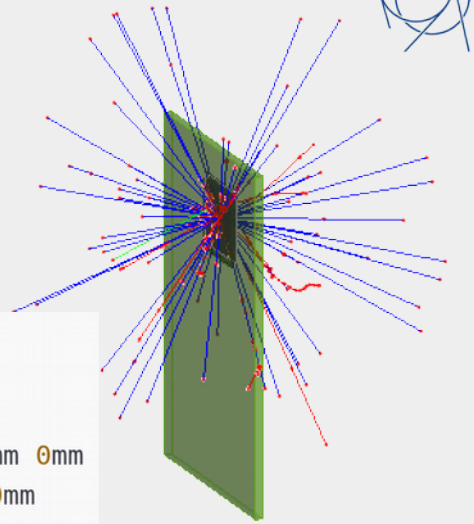
User Manual:
https://cern.ch/allpix-squared/usermanual/allpix-manual.pdf


CERN

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

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

```
[DepositionGeant4]
source_type = "sphere"
sphere_radius = 5cm
sphere_focus_point = 0mm 0mm 0mm
source_position = 0mm 0mm 0mm
```

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

```
[DepositionGeant4]
particle_type = "Fe55"
source_energy = 0eV
source_position = 0 0 -1mm
source_type = "point"
number_of_particles = 1
```