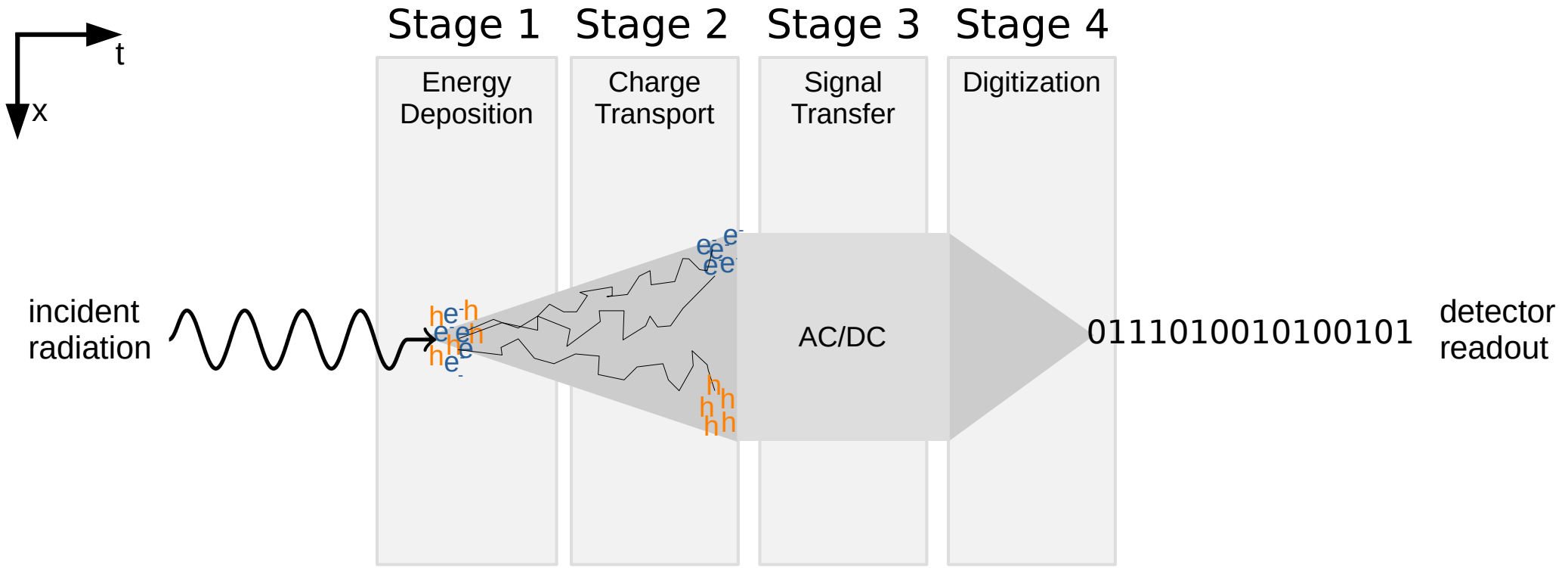
2nd Allpix Squared User Workshop – Recap

Paul Schütze
for many others

Silicon Dector R&D Meeting
1. September 2021

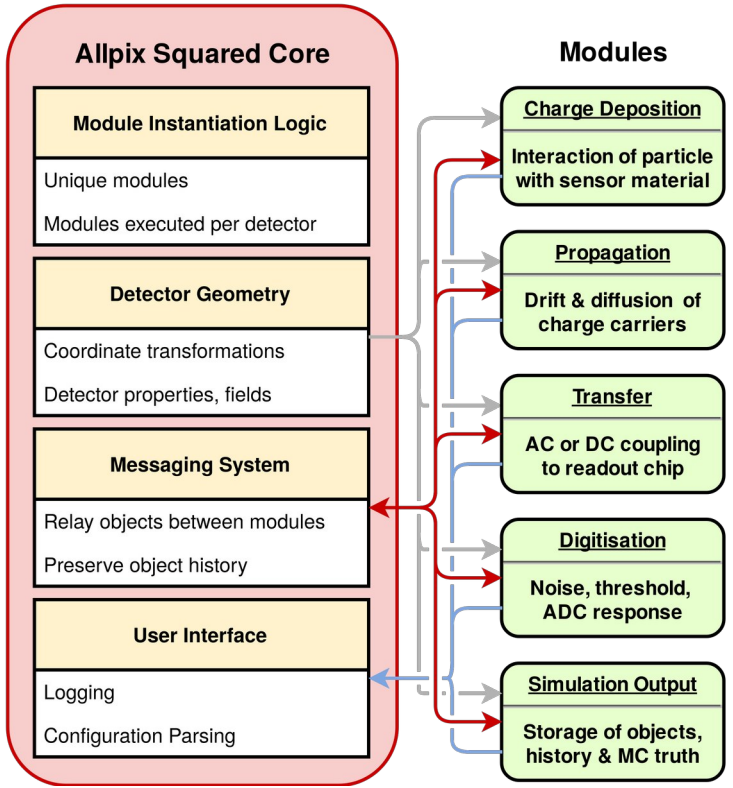
Allpix Squared
–
Monte Carlo Simulations for Silicon Pixel Detectors

Particle Detection in Silicon Sensors



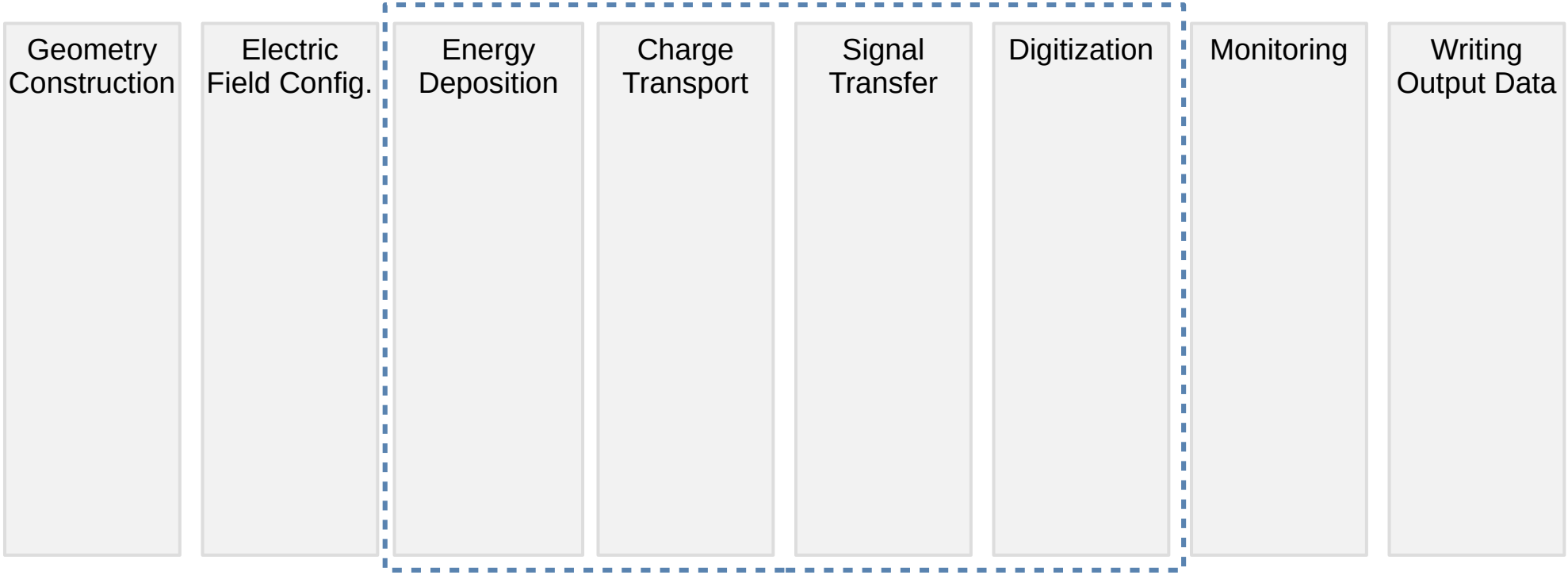
The Allpix² Framework

- Flexible MC simulation software, that
  - ...allows to test different simulation models for signal formation
  - ...implements parametrized detector models
  - ...facilitates usage of precise electric fields
- Focus on usability & stability
  - Separate infrastructure from physics
  - Easy setup & configuration
  - Provide documentation (160p. user manual)
  - Regular patch & feature releases
    - 27 releases – more than 30 contributors



Simulation Flow

- Building blocks follow individual steps of the signal formation in detectors
- Algorithms for each step can be chosen independently



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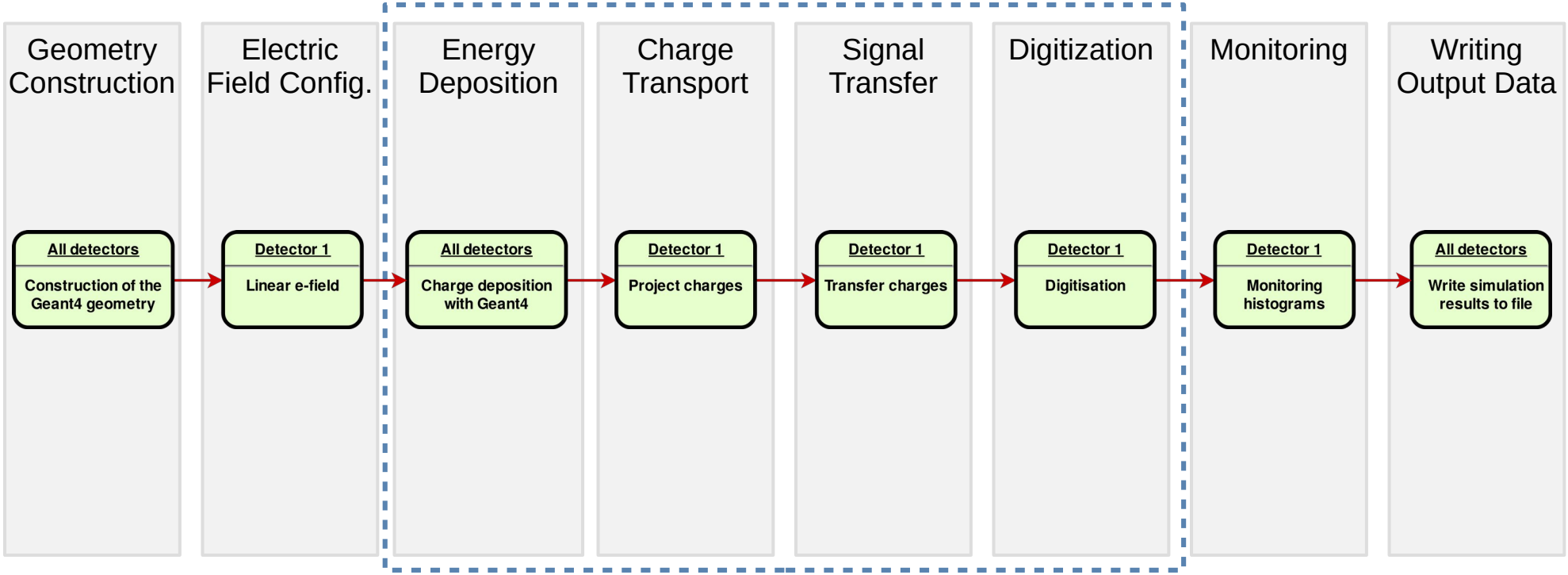
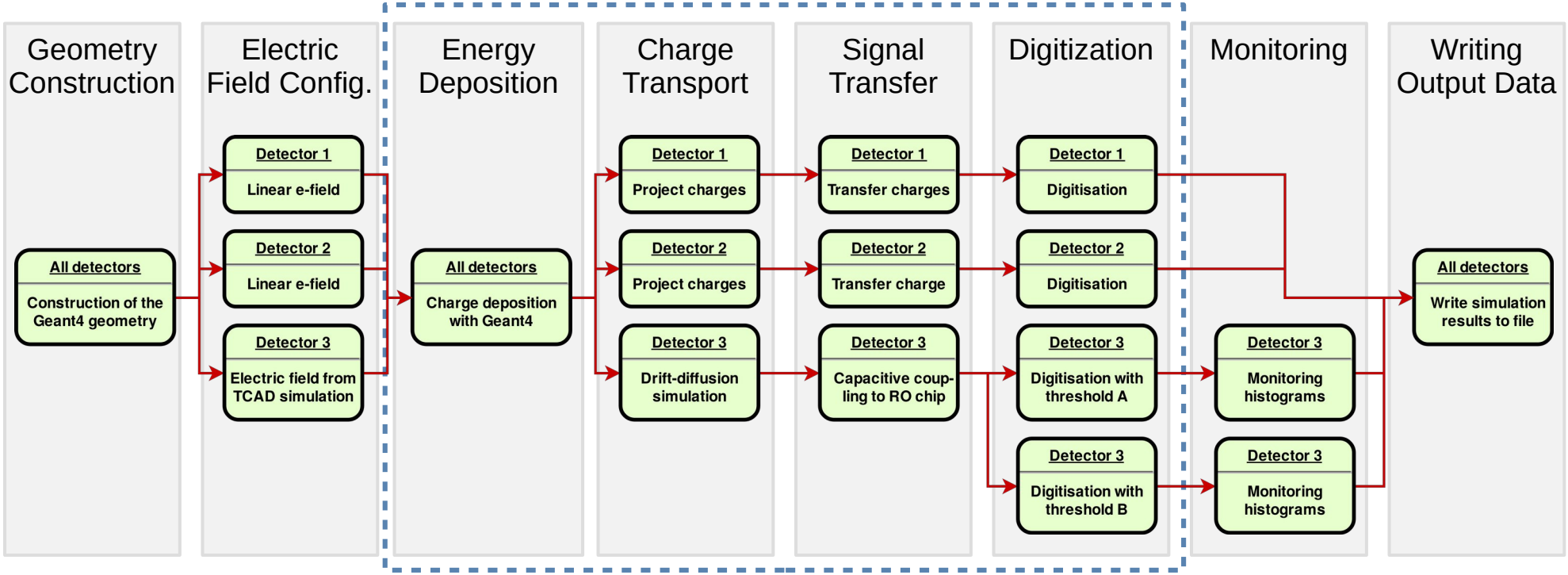


Simulation Flow

- Simulation very flexible: modules configurable on per-detector level
- Multiple instances can be run in parallel (e.g. to simulate different front-ends)



Allpix²
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orkshop

ugust 2021 Wherever you are (virtual)

adlines:

Abstract submission: **24 July 2021**
Registration: **16 August 2021**

ancas (DESY)
lyka (DESY)
rt (CERN)
(DESY)
nagel (DESY)

- **New Features**
- **Software Development**
- **Expert Talks**
- **User Applications & Studies**
- **Simulation Case Studies**

For registration and abstract submission, please scan the QR code or go to: **https://indi.to/WhdJn**

2nd Allpix² User Workshop

17-19 August 2021 **Wherever you are (virtual)**

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Adriana Simancas (DESY)
Anastasiia Velyka (DESY)
Katharina Dort (CERN)
Paul Schütze (DESY)
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- **User Applicati**
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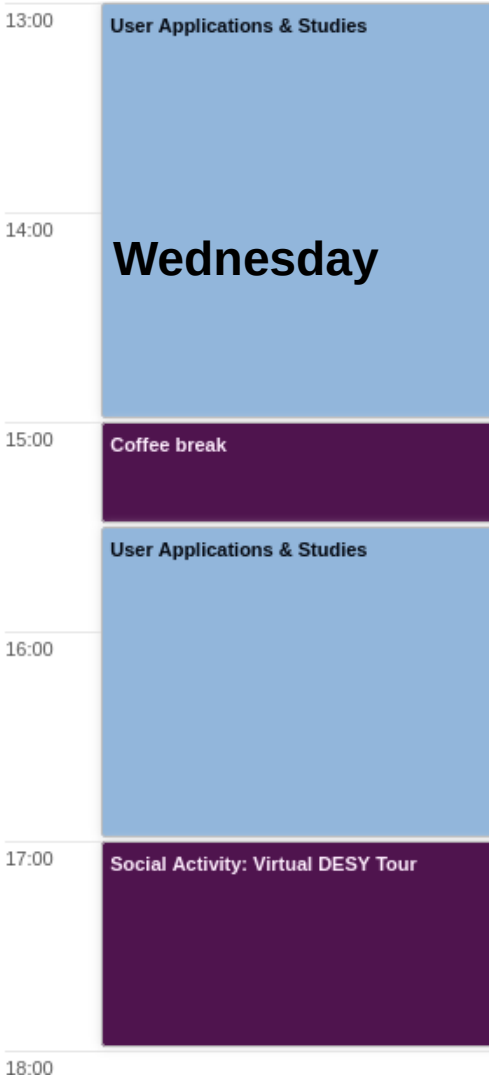
Timetable

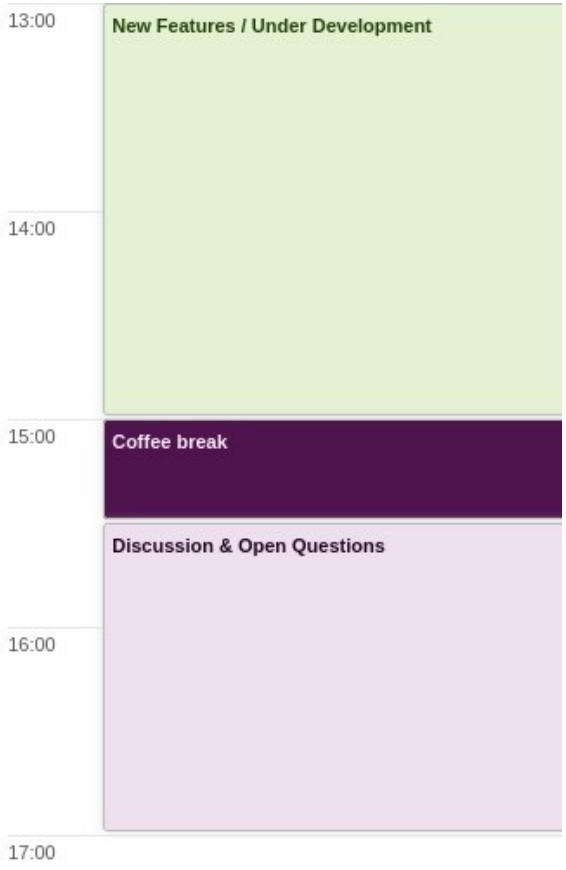
https://indico.cern.ch/event/1043567/

Tuesday

Wednesday



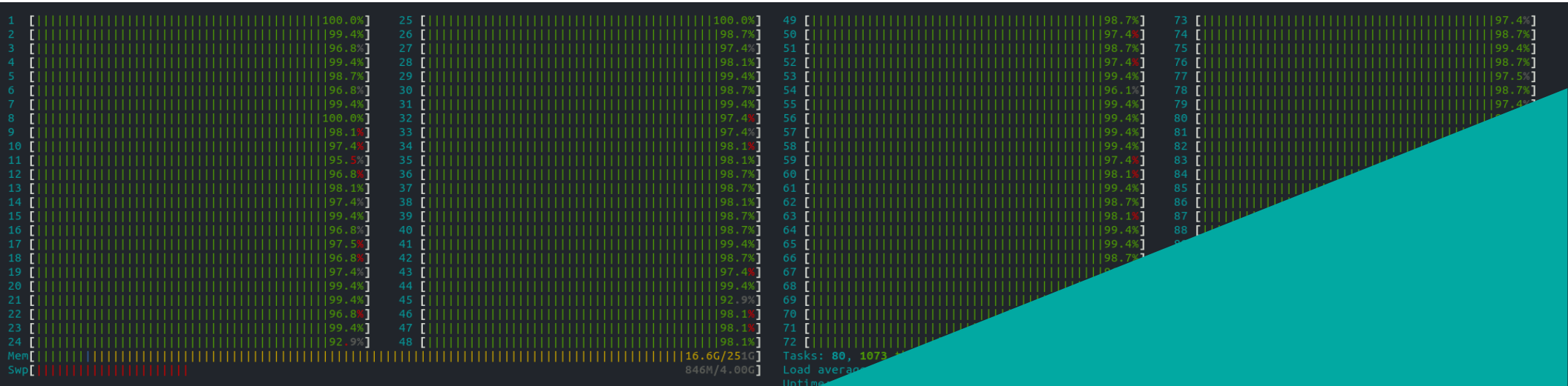
Thursday



Workshop Summary

Caveat:
Very condensed information below!
Refer to the individual presentations for detailed information.

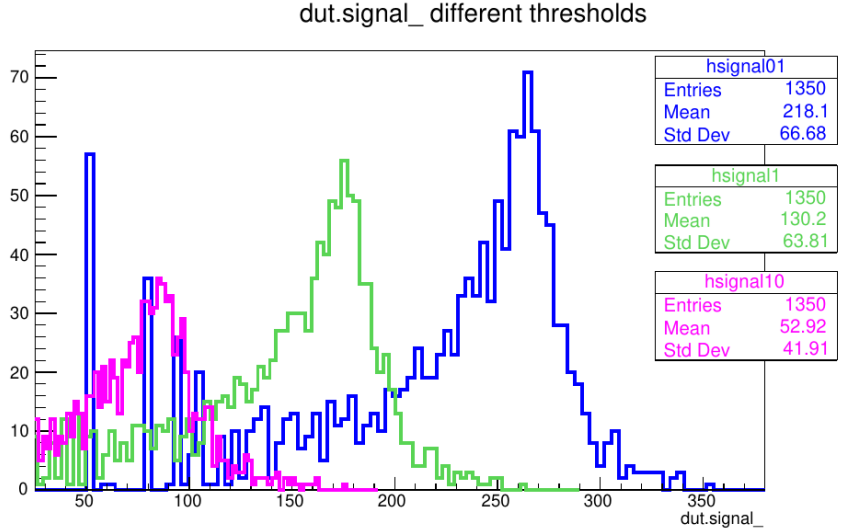
Software Development

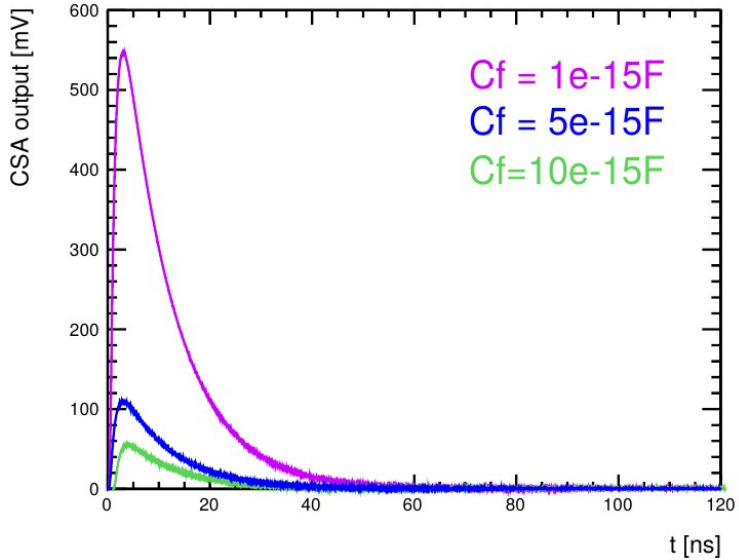


CSA Digitzer – A. Vauth (DESY/UHH)

- Feature overview
- Usage examples

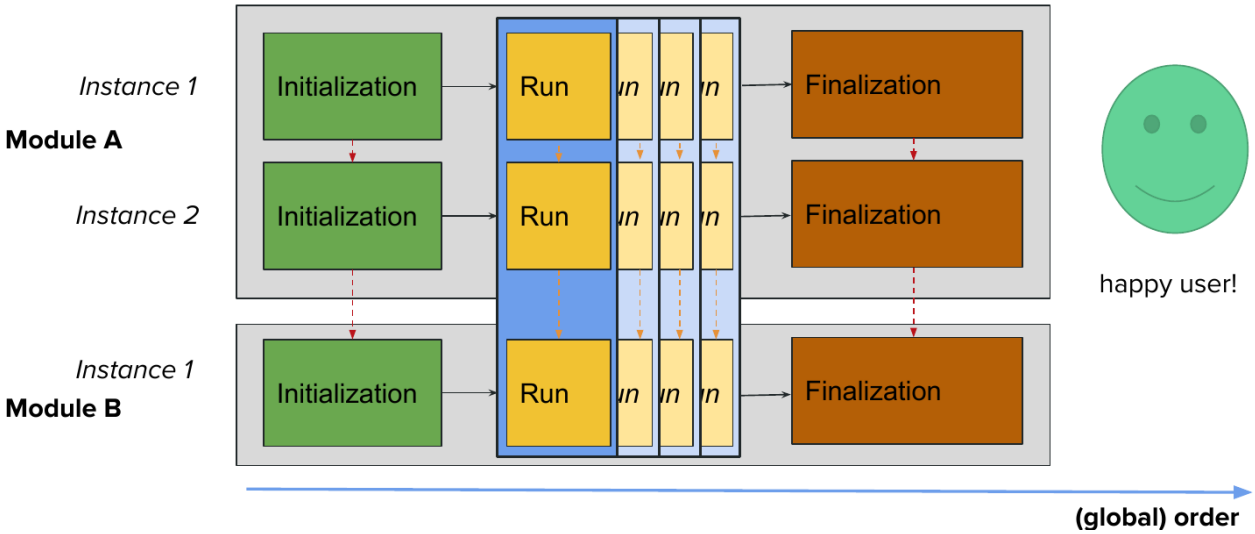
Time-over-Threshold for different thresholds (0.1mV , 1mV , 10mV)



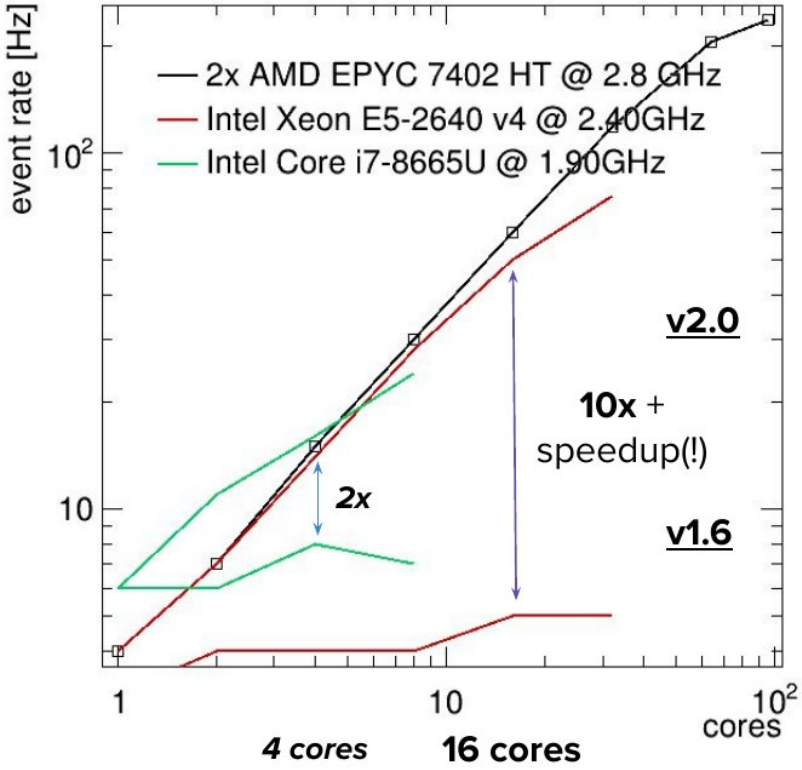


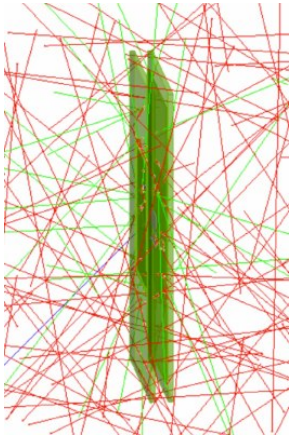
Multithreading – K. Wolters (CERN/Google)

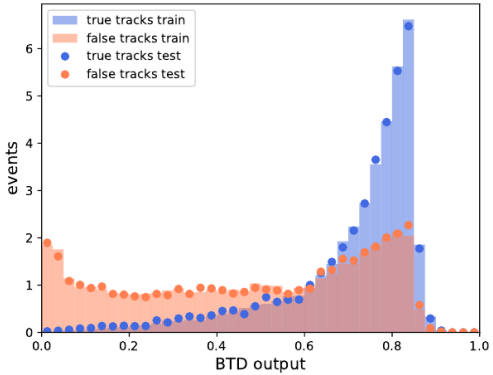
- Report on …
  - Basic concept
  - Issues during implementation
  - Benchmarking results



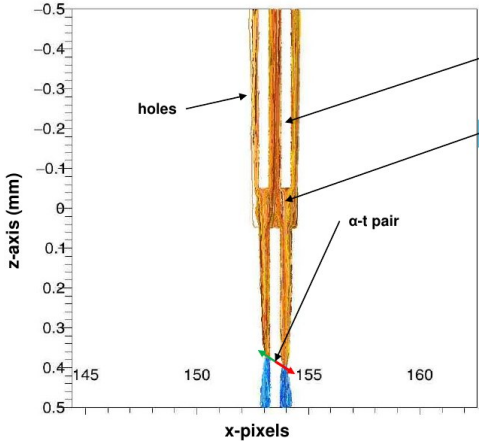
happy user!

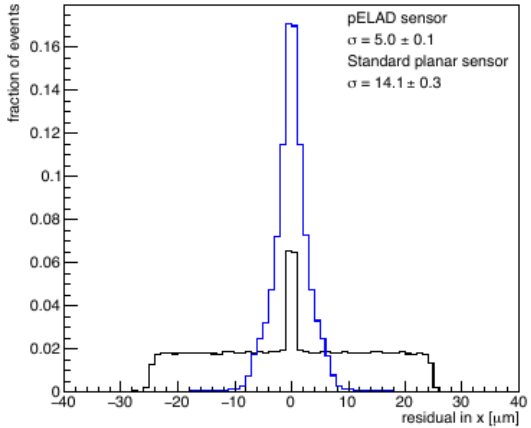


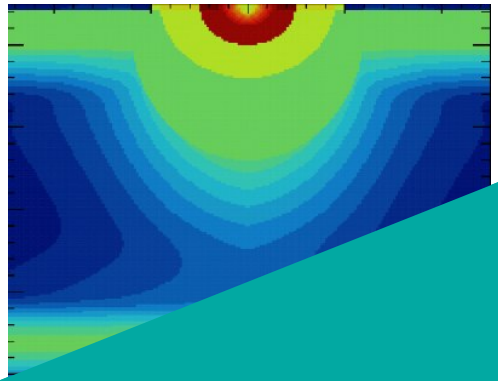




User Applications & Studies

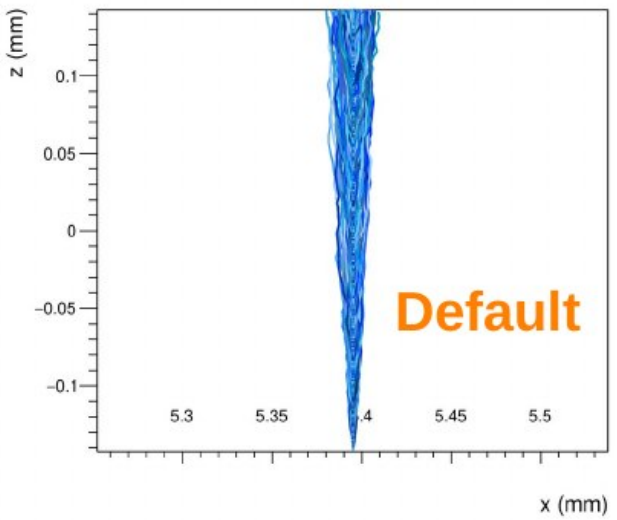


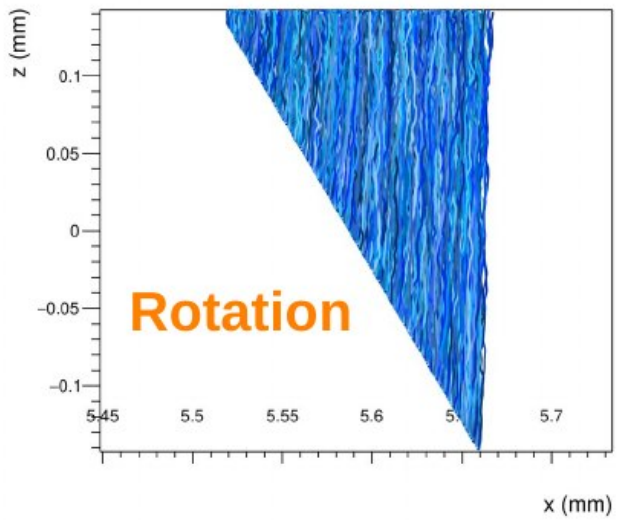


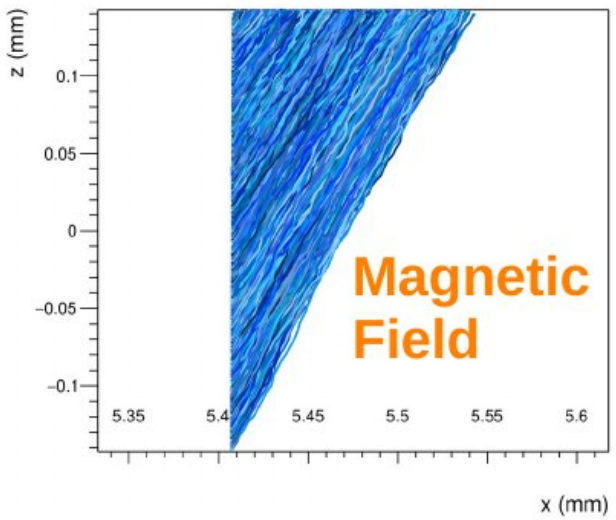


Allpix² in Edu&Outreach – me

- Lab course designed by Simon & me:
  - Target level: Bachelor students to PostDocs
  - Gain understanding on silicon detectors
  - Gain experience in computing (Command line, ROOT, Geant4, Allpix²)

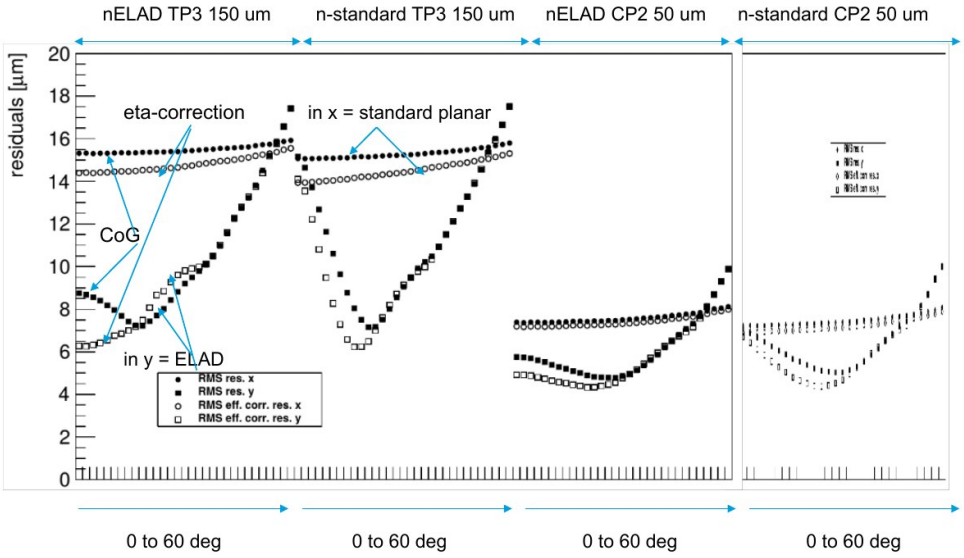


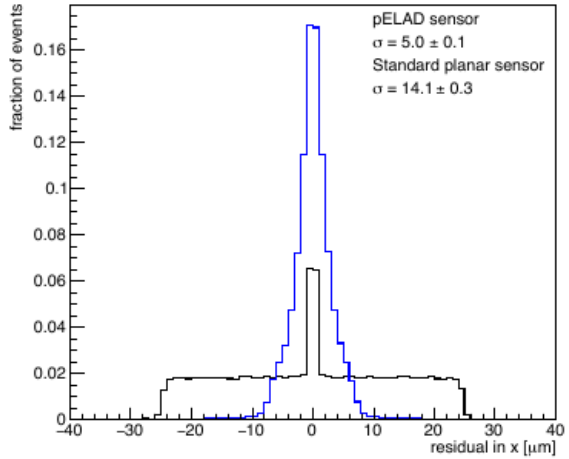




ELAD Sensors – A. Velyka (DESY)

- Sensor design study
  - Sensor design & electrostatic field calculations via TCAD → Field export
  - Monte Carlo simulation of response to particle passage for several prototypes
  - Focus of study: cluster size & sensor resolution

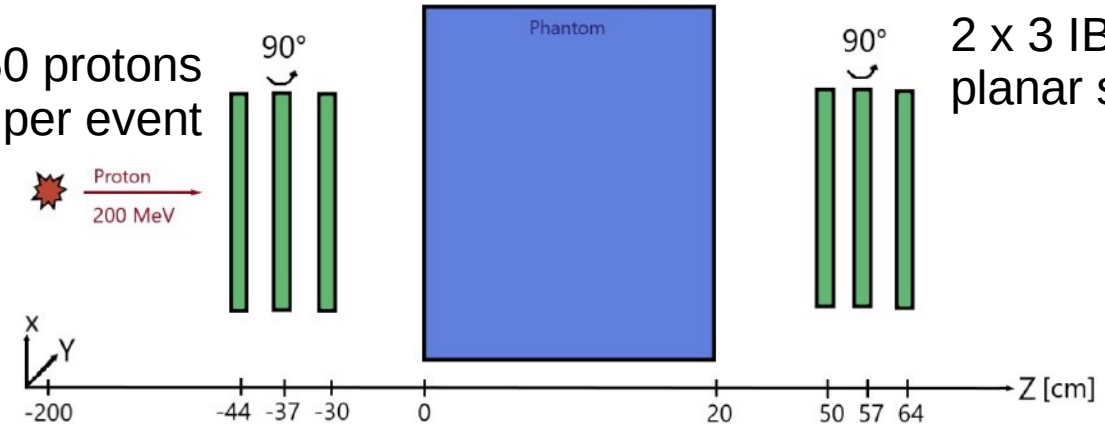




Proton CT – C. Krause (TU Dortmund)

- Simulation of imaging setup: determination of multiple scattering angle in phantom

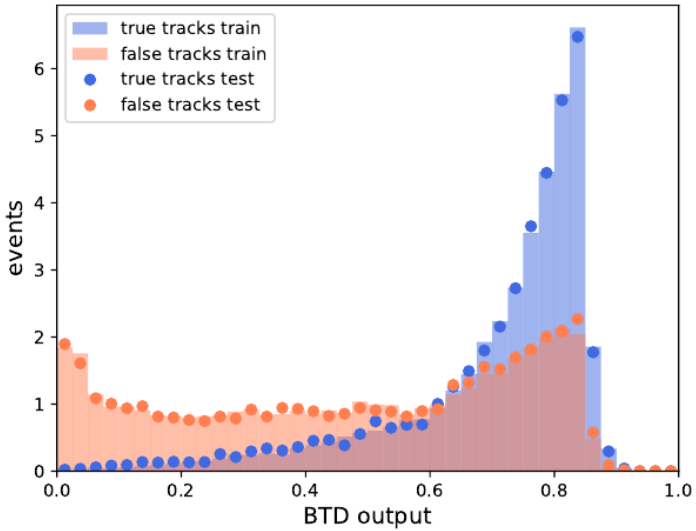
25-50 protons per event



2 x 3 IBL planar sensors

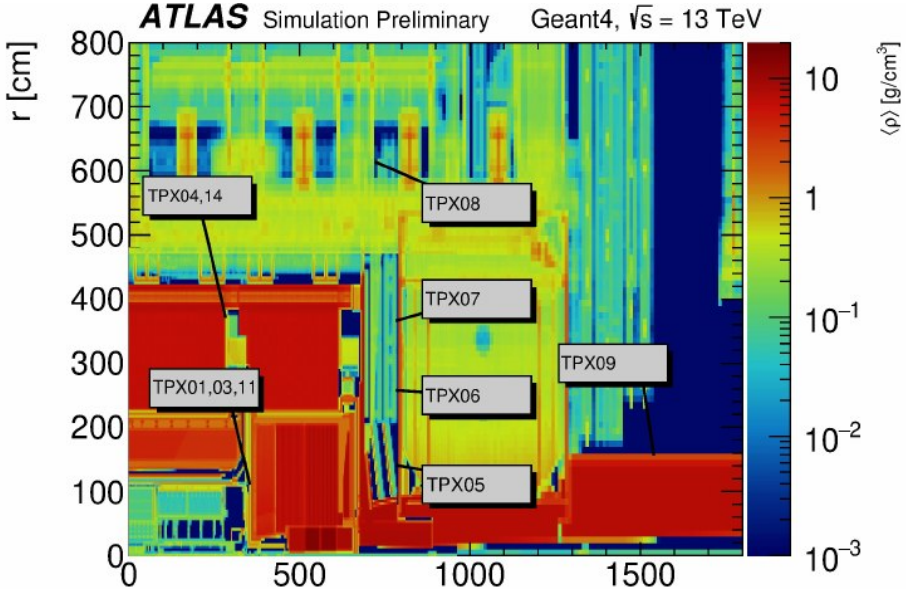
- Issue: after track reconstruction via Corryvreckan, more tracks than simulated protons available

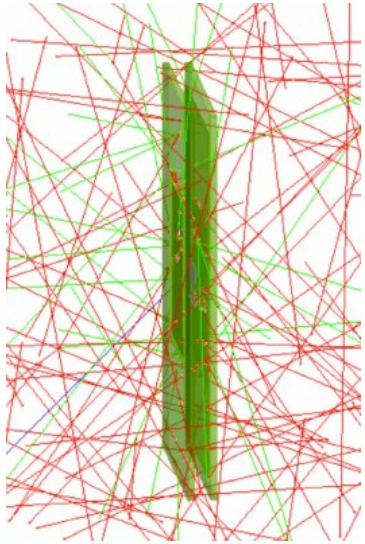
➔ Study: Improve track selection via Machine Learning

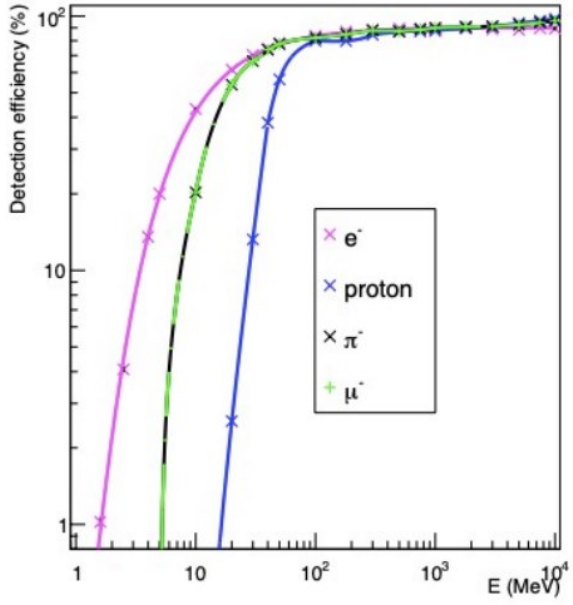


Radiation Detection – T. Billoud (CTU)

- Using Timepix detectors for benchmarking radiation field simulations in ATLAS





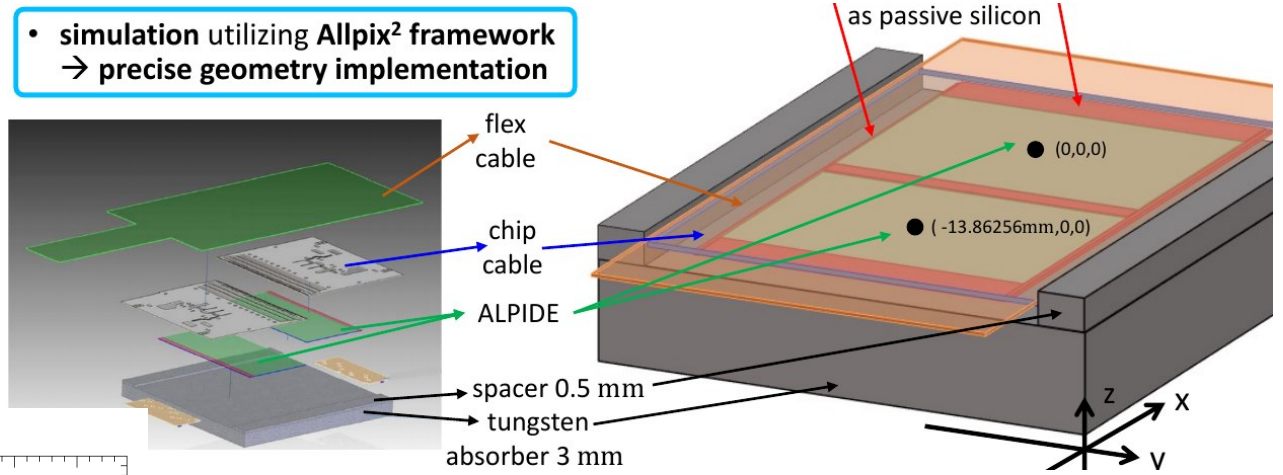


- Use Allpix² to predict detection efficiency for the interpretation of the Geant4 simulation

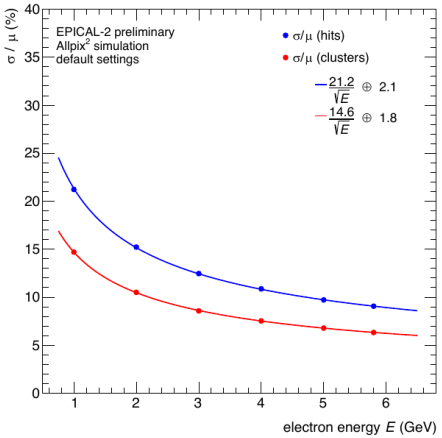
Sim of MAPS ECAL TB data – T. Rogoschinski (Uni Frankfurt)

- FoCal experiment, ALICE
- 24 layers of …
  - 2 x ALPIDE
  - 3 mm tungsten

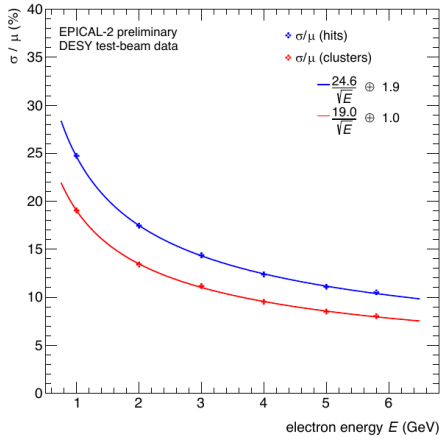
- **simulation** utilizing **Allpix² framework**
  → **precise geometry implementation**



simulation



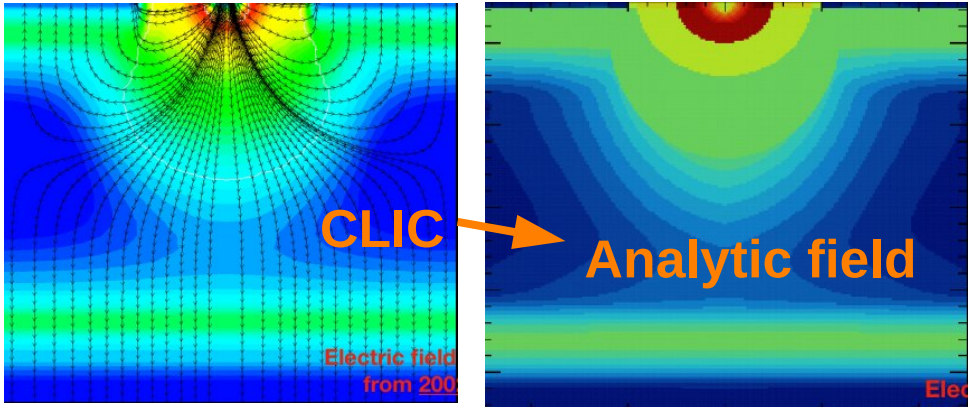
test-beam data

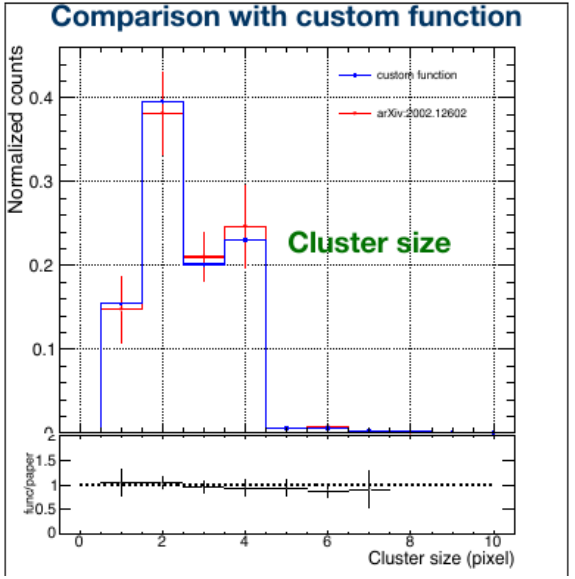


- Allpix²: Full calorimeter simulation vs test beam
- Good agreement of simulation & TB data
- Caveat: beam profile & beam energy spectrum still require adjustment

LUXE Tracker – A. Santra (Weizmann)

- Alpide pixel sensors
- Allpix²: Digitisation of energy deposits from full-detector Geant4 simulation
- Main study presented: find analytic description for the electric field for MAPS devices

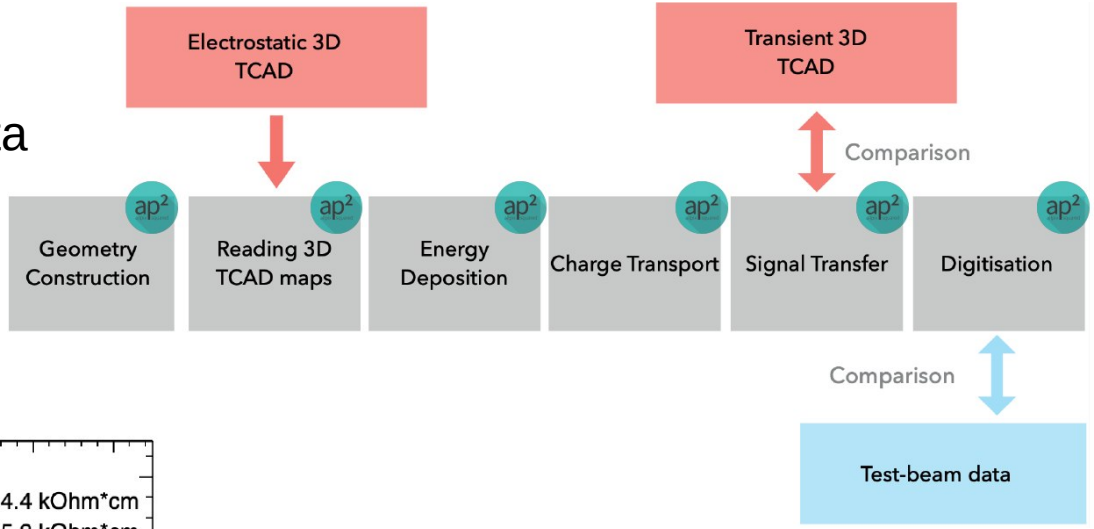


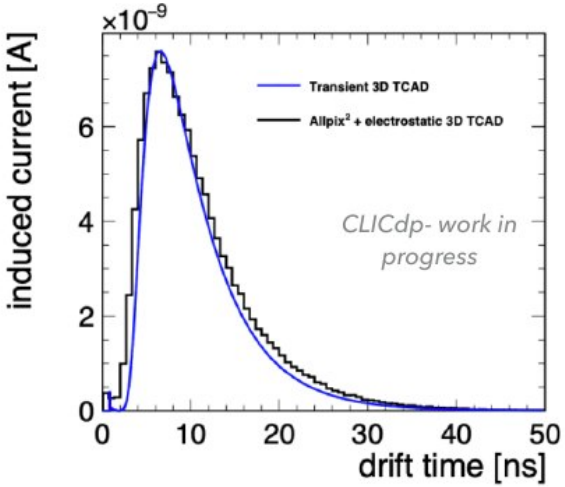


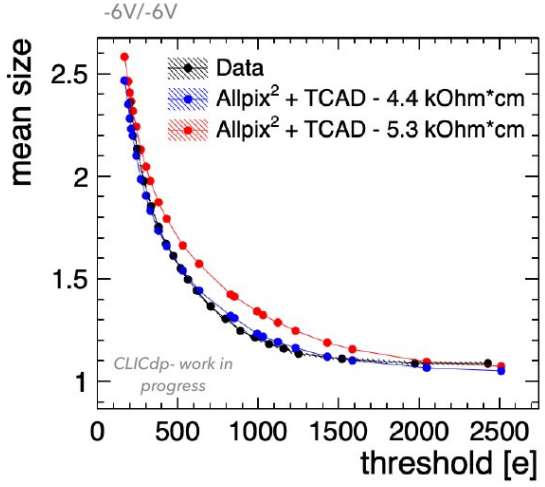
- Cluster size, resolution, efficiency & charge as observables
- Managed to get a good overlap

Transient Sim of CMOS sensors – K. Dort (CERN)

- 180 nm CMOS imaging process
- Comparison to TCAD & Test Beam data for several sensor designs
- Good agreement found





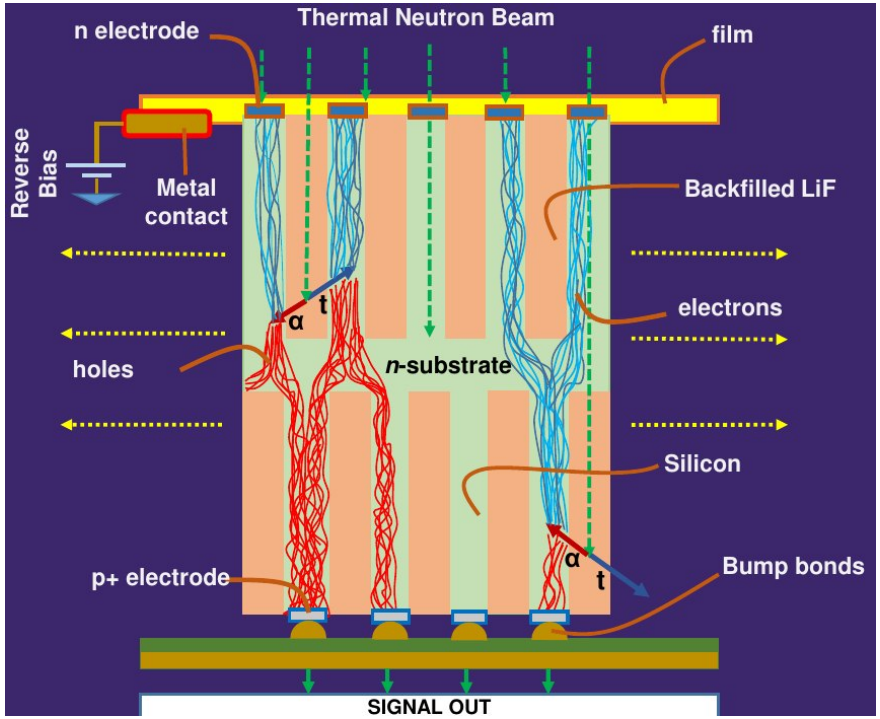


- The *Triple* TCAD import: Electric field, doping profile, weighting potential

➔ Includes **charge carrier recombination** (Auger + Shockley-Read-Hall) & **current induction** (Shockley-Ramo)

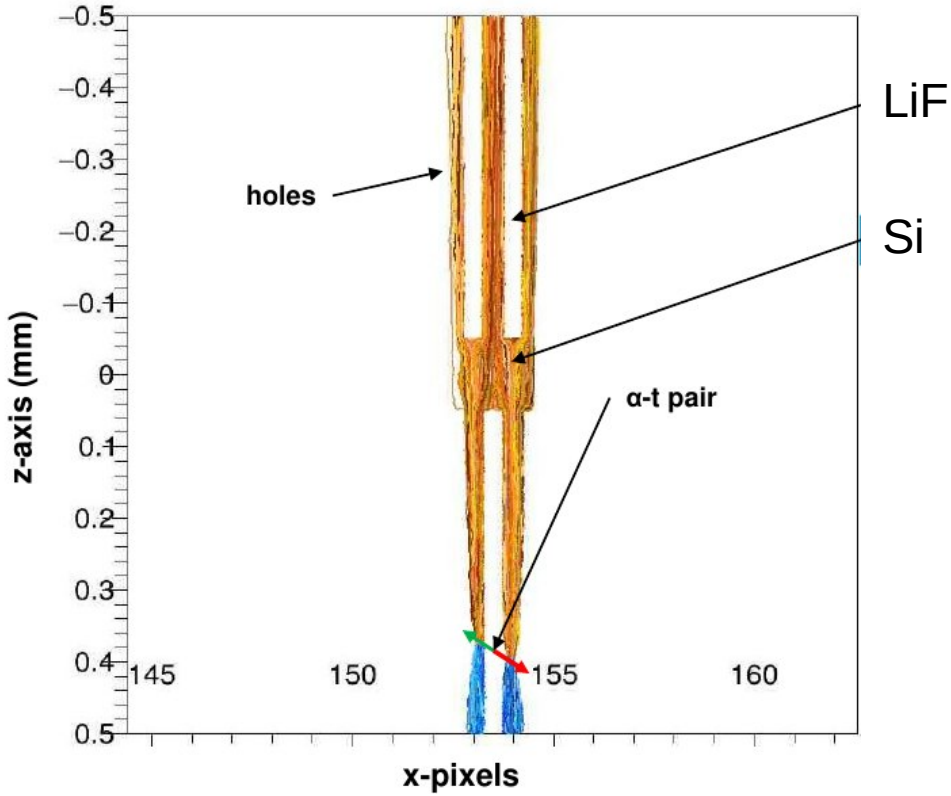
Semiconductor Neutron Detector – S. Sharma (KSU)

- Si sensor with LiF trenches for neutron conversion: $\mathrm{n} \rightarrow \mathrm{t} + \alpha$
- Comsol: electric field & weighting potential
- Allpix²: the rest



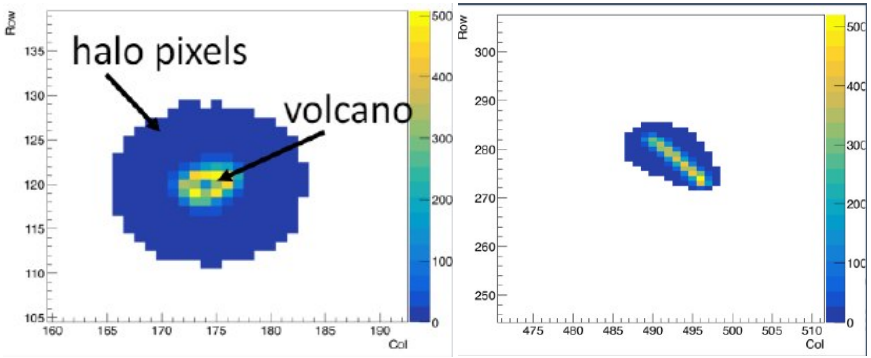
Semiconductor Neutron Detector – S. Sharma (KSU)

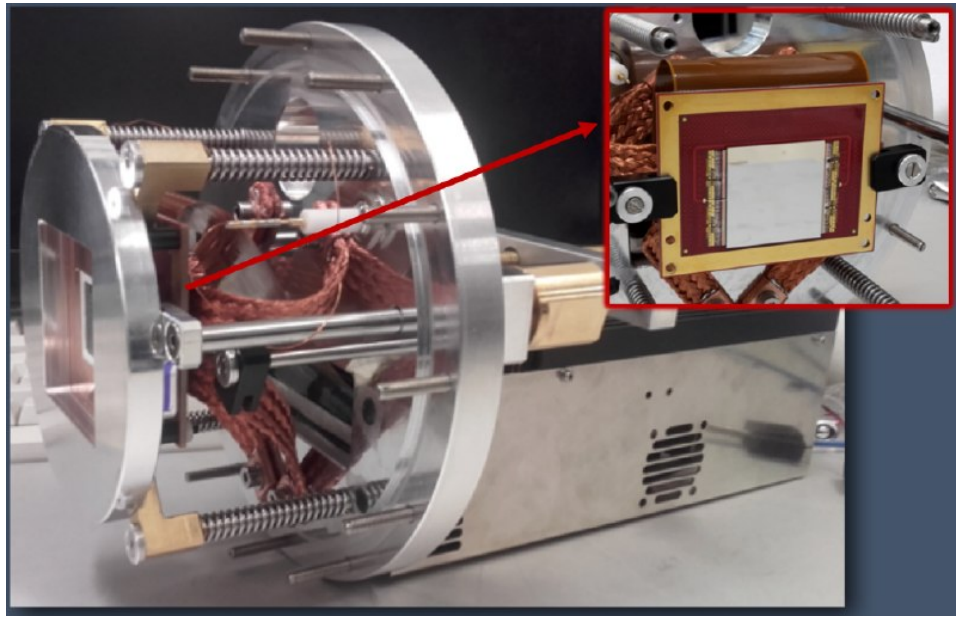
- Si sensor with LiF trenches for neutron conversion: $\mathrm{n} \rightarrow \mathrm{t} + \alpha$
- Comsol: electric field & weighting potential
- Allpix²: energy deposition (Geant4), charge transport, signal, efficiency
- Study:
  - Detection efficiency
  - Gamma ray rejection techniques via cluster morphology



Antiproton Annhihilation – G. Costantini (Uni Brescia)

- Antiproton Decelerator → ASACUSA
  - 2 x 2 Timepix3 matrix
- Geant4: energy deposit
- Allpix²: digitisation & comparison to data
- Issue: description of *volcano effect* and cluster *halos* for high charge clusters



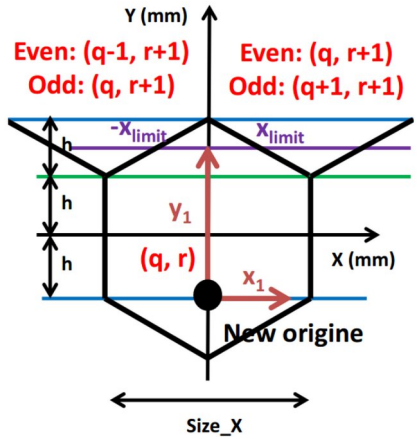


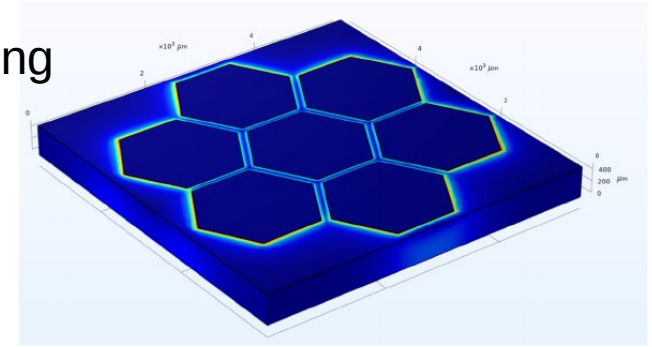
- Front-end saturation in Allpix² is not sufficient to describe the effect

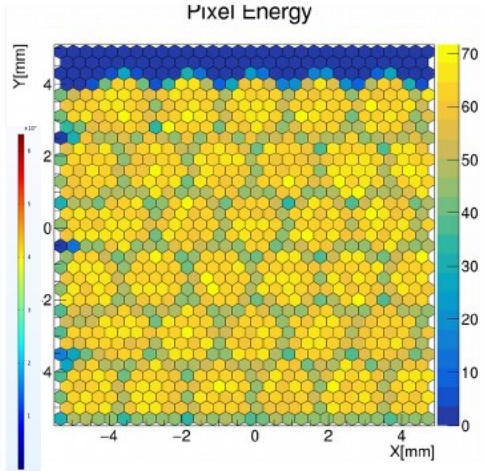
➔ Discussion: Halo: Current induction at neighbour pixels? → Weighting potential required?

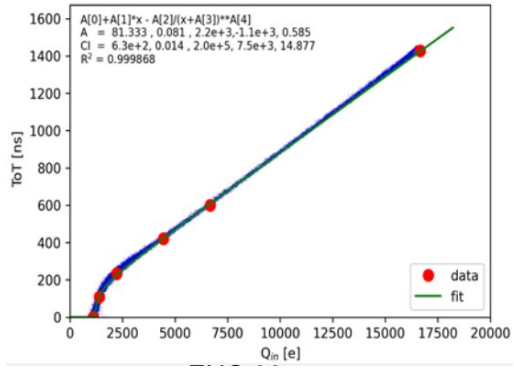
Germanium Detectors for Synchrotron Radiation – T. Saleem (SOLEIL)

- X-ray detection with hexagonal Ge detectors @30-70 keV
- Allpix² for simulation of sensor response
- Diverged code with hardcoded changes:
  - $\mathrm{Si} \rightarrow \mathrm{Ge}$ (Material, Mobility, Fano factor, charge creation)
  - Hexagonal pixels
- Hexagonal field exported from COMSOL
- Design studies performed & ongoing

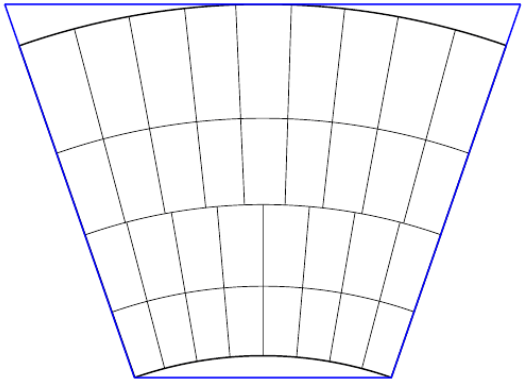


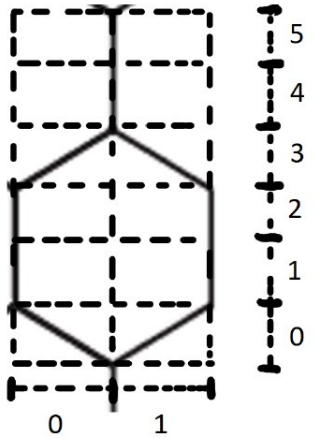






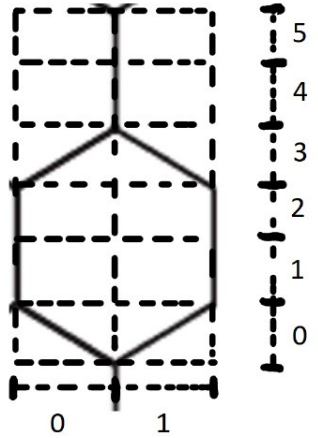
Ongoing Developments

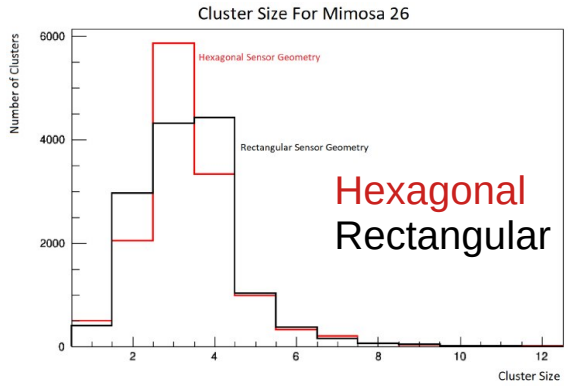


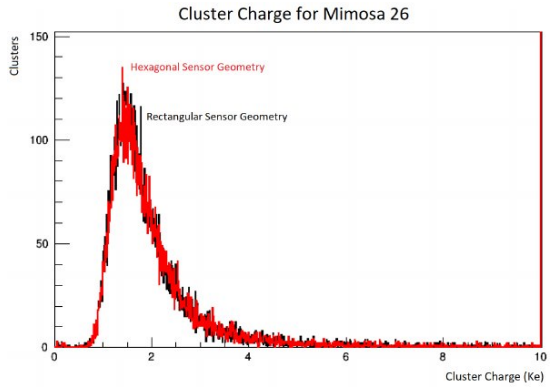


Hexagonal Pixels – R. Moriya (CERN)

- Add hexagonal pixel design as an configurable alternative to rectangular pixels
- Main challenge (so far):
  Calculation of pixel index for a given local position “on sensor”
  - Solution: define rectangular unit cells, split into 12 regions
  - Pixel assignment & equations defined for each region
- Successful implementation
- Merge Request under review
- Discussion: Implementation & Import of TCAD fields for hexagonal pixel detectors

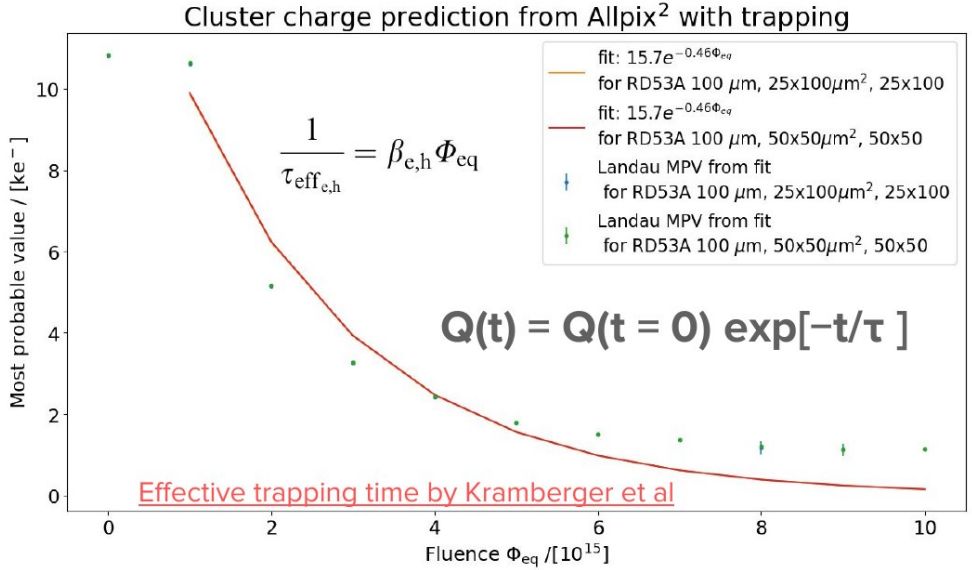






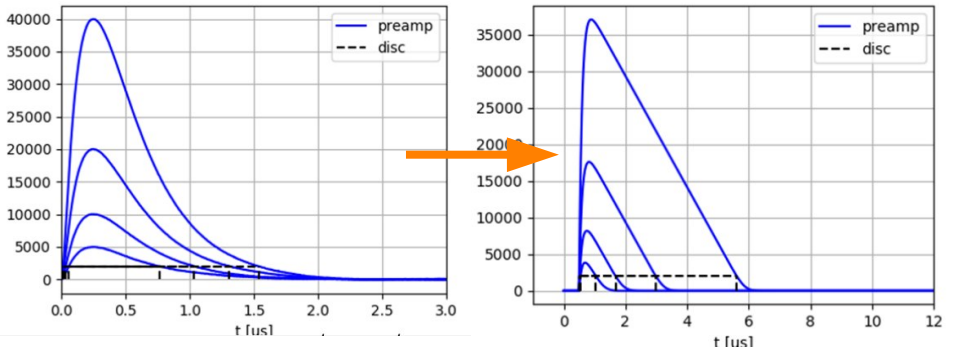
Trapping/Radiation Damage – J. Sonneveld (Nikhef)

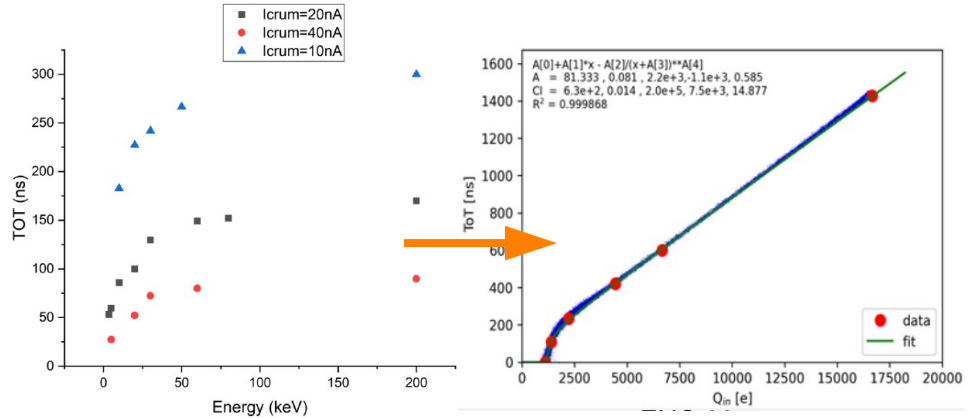
- Field of radiation damage is untouched yet
- Approach: implement trapping
- Technique:
  - Calculate trapping time (Kramberger model, discussed others)
  - Reduce the charge of a charge carrier group accordingly
- Work ongoing:
  - *Validation* against test beam data
  - Move implementation to Models
- Discussion:
  - Trapping gives an incomplete picture for RadDamage – how to proceed?



Digitizer with Krummenacher CSA – P. Christodoulou

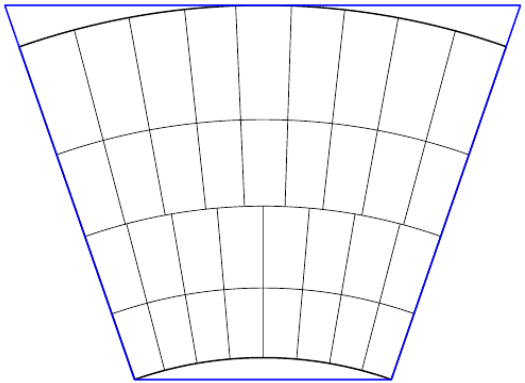
- Current implementation of CSADigitizer:
  - Output describes Krummenacher feedback & shaper
  - ➔ Technique: convolution of signal and CSA response
  - ➔ Saturates for high signals
- This implementation:
  - Output shape depends on input (feedback current)
  - ➔ Describes e.g. TPX3 behaviour better
- Comes with additional parameters
- Work in progress:
  - Method optimisation
  - Validation against data

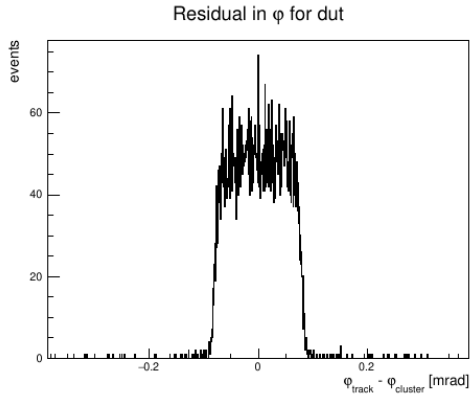




Radial Strip Detectors – R. Privara (Olomouc)

- Simulation of ATLAS Itk Strip detector
  - Geometry: radial strips
  - ➔ Requires re-work in detector geometry:
    Calculation of pixel index for a given local position “on sensc
- Implementation status:
  - Define “inner pitch”, angular pitch and strip length in geometry
  - Usage of polar coordinates for charge assignment to strip
- Preparation work in framework core completed:
  - Make geometry and coordinate transformations more flexible
  - ➔ Implementation of hexagonal pixels already based on this





Conclusion

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- 63 Registrants – 21 Contributions – Time for discussions
- Social Programme: virtual DESY Tour (thanks to all people involved)
- We (as developers, users & participants) …
  - got an overview over applications, status and needs of users
  - are eagerly waiting for ongoing developments to converge & merge