Integration of the ACTS track reconstruction toolkit in the ATLAS software for HL-LHC operations

Rosie Hasan (RHUL & RAL)
On behalf of the ATLAS Collaboration
Supervisors: Dr T Adye & Dr T Berry
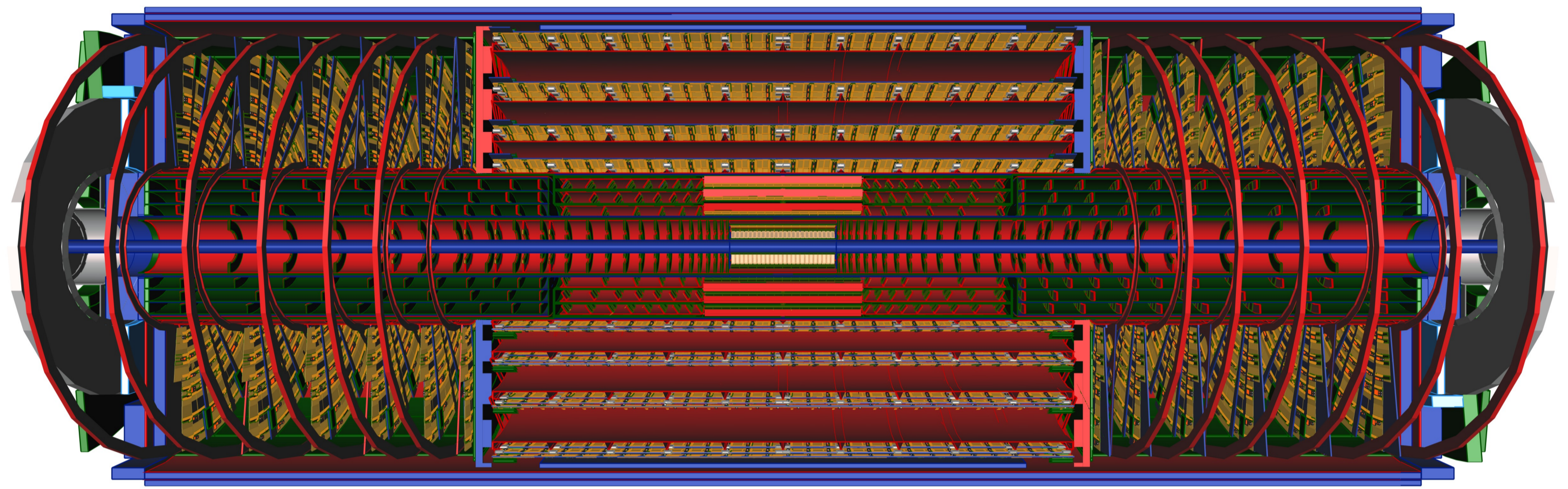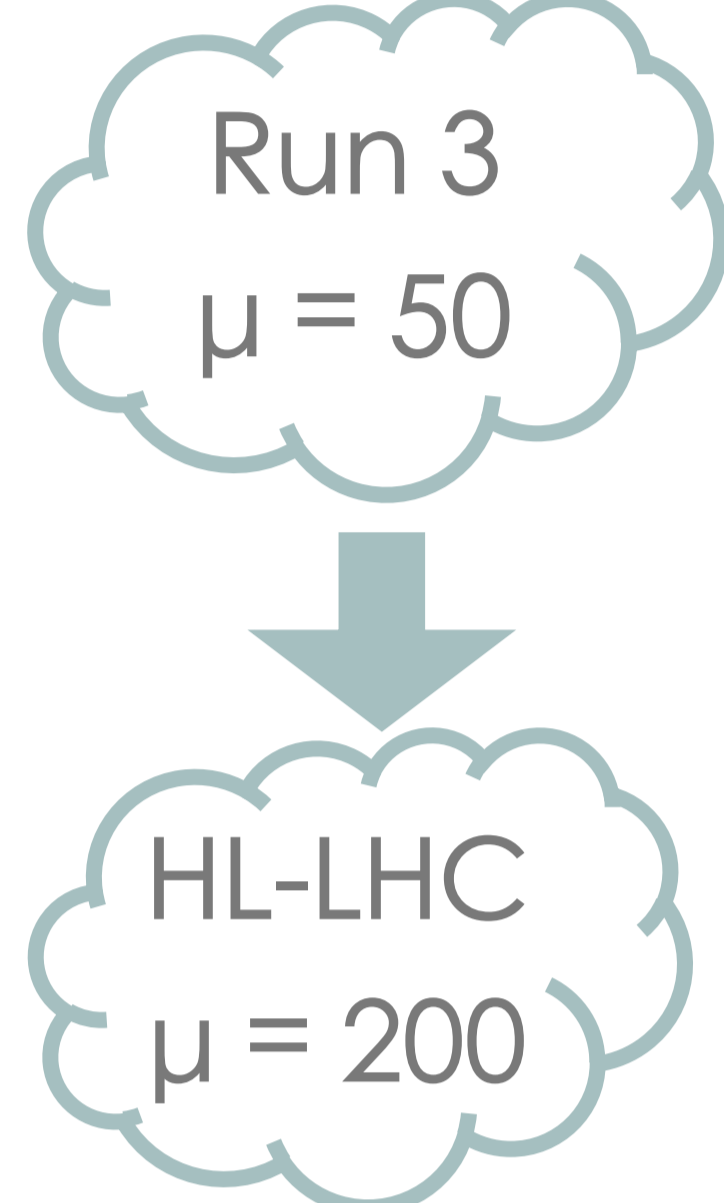rosanne.zara.hasan@cern.ch

HL-LHC

The High Luminosity LHC (**HL-LHC**), is set to begin in 2029, and will be Run 4+ of the ATLAS detector.

Increase in **pileup**, μ, (number of interactions per crossing) → More tracks → More complex track reconstruction

Inner tracking system to be replaced with an all-silicon Inner Tracker (**ITk**).

Run 3
$\mu = 50$

HL-LHC
$\mu = 200$

Software upgrade
- Maximise physics performance
- Modernise the software technology
- Support new processing accelerators (eg. GPU, FPGA)
- Ensure maintainability throughout the operation of the experiment
- Minimise CPU/RAM resource usage

ACTS

ATLAS will extensively use **ACTS**- A Common Tracking Software for the Run 4 reconstruction software.

ACTS algorithms are designed to be experiment independent.

New and current ATLAS tracking software is being integrated into this platform.

Benefits
- Platform for research and development
- Experiment independent
- Thread-safety
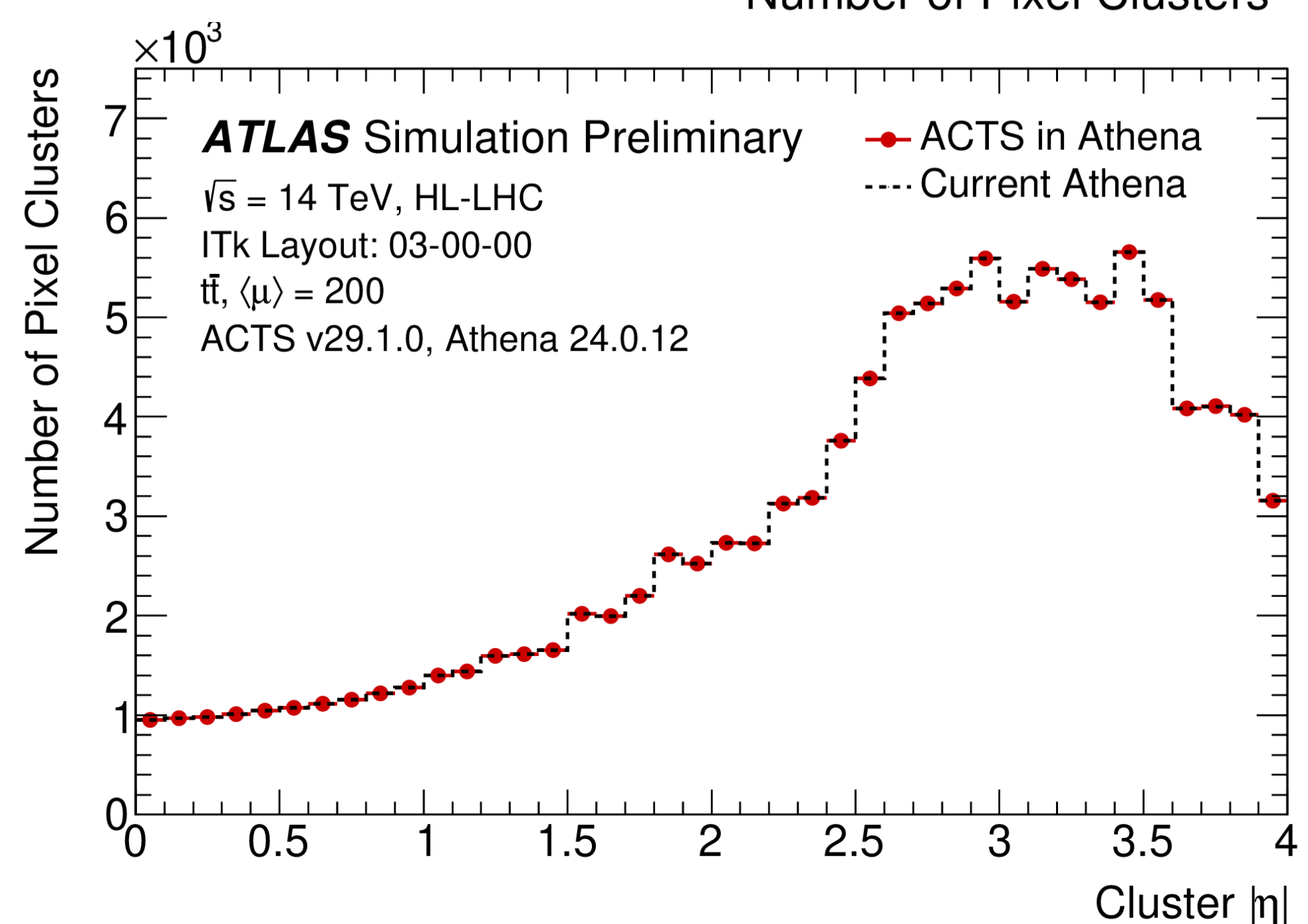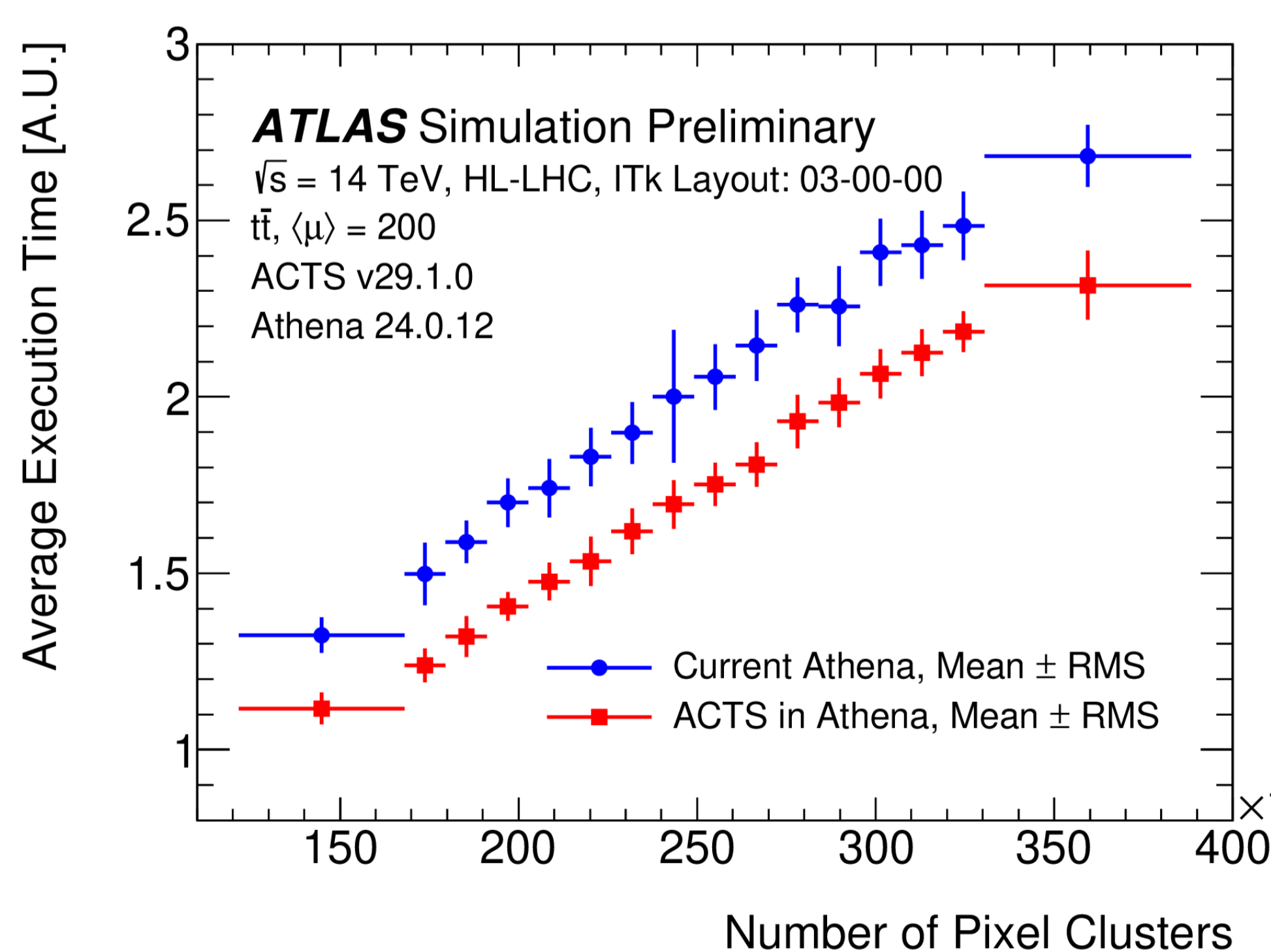- High performance
- Code maintainability

Tracking chain

Tracking algorithms aim to reconstruct particle tracks.

Full ACTS-based tracking chain now implemented for the ITk

- **Clusters** : adjacent hits are grouped together
- **Space points** (black dots): three-dimensional representations of clusters
- **Seeds**: triplets of space points
- Seeds are then **filtered** using an iterative, Combinatorial Kalman filter
- **Track candidates**: tracks are made by extending seeds and the parameters are estimated using Combinatorial Track Finder (CKF)
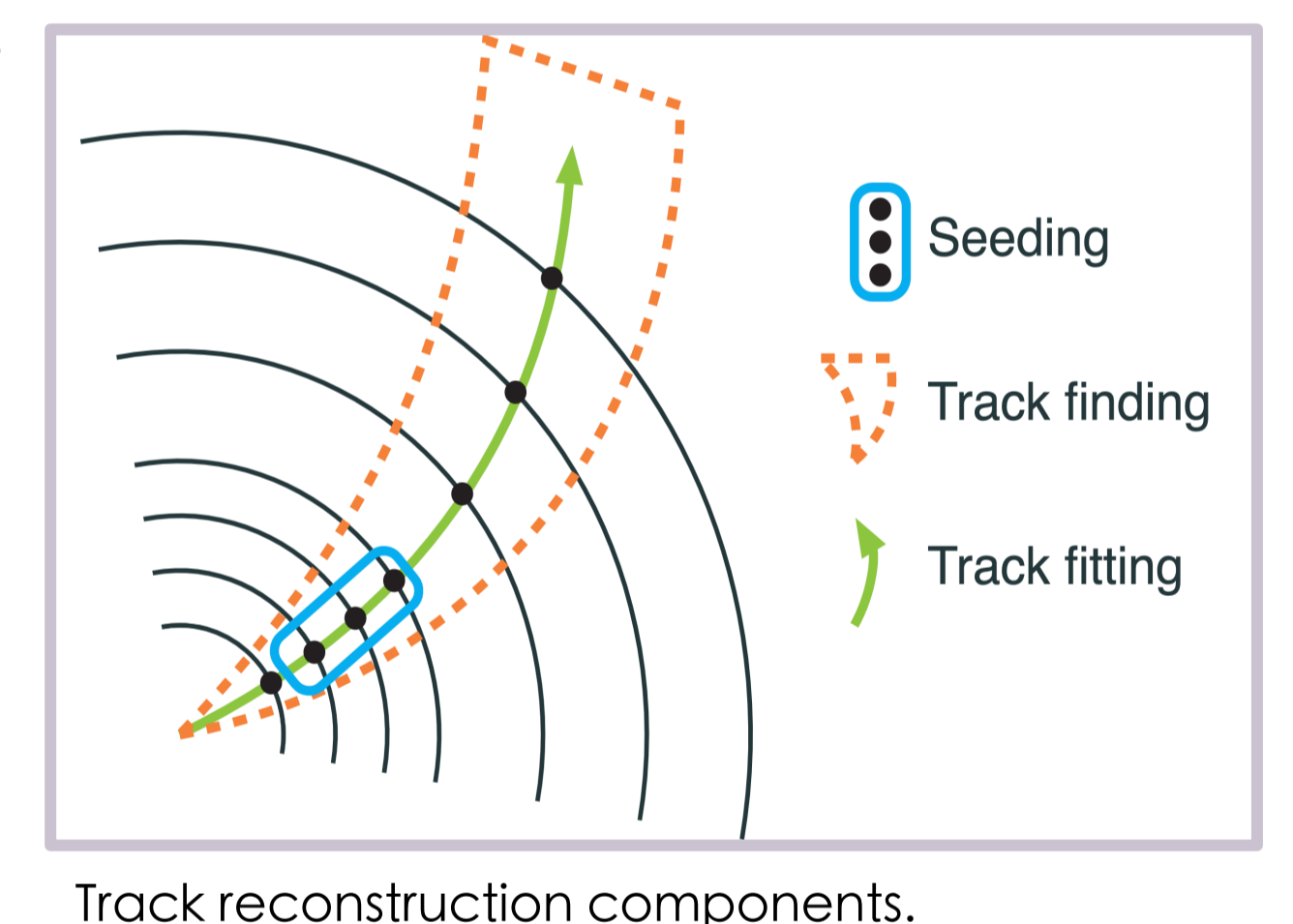
Requirements:
- High efficiency
- Low fake rate
- High precision track parameters
- Fast

- Seeding
- Track finding
- Track fitting

Track reconstruction components.

Measurements → Clusterization → Clusters → SP Formation → Space Points → Seeding → Seeds → Track Finding → Track Candidates → Ambiguity Resolution → Tracks

Performance Measurements

ATLAS Simulation Preliminary
$\sqrt{s}$ = 14 TeV, HL-LHC, ITk Layout: 03-00-00
$t\bar{t}$, $\langle\mu\rangle$ = 200
ACTS v29.1.0
Athena 24.0.12

- Current Athena, Mean ± RMS
- ACTS in Athena, Mean ± RMS

Clustering
- ACTS clustering is a modified version of current ATLAS implementation
- Identical physics results: **100%** agreement of number of clusters and cluster sizes
- Constant timing improvement: average timing improvement per event of ∼**15%**

Seeding
- Reimplementation of ATLAS seeding
- Reproduces 1-1 identical seeds
- ∼10% slower: ongoing optimization

Track Finding
- Reimplementation and improvement of ATLAS CKF
- Ongoing physics and resource optimization

ATLAS Simulation Preliminary
$\sqrt{s}$ = 14 TeV, HL-LHC
ITk Layout: 03-00-00
$t\bar{t}$, $\langle\mu\rangle$ = 200
ACTS v29.1.0, Athena 24.0.12

- ACTS in Athena
- Current Athena

ATLAS Simulation Preliminary
$\sqrt{s}$ = 14 TeV, HL-LHC
ITk Layout: 03-00-00
$t\bar{t}$, $\langle\mu\rangle$ = 200, Truth p_T > 1 GeV
ACTS v29.1.0, Athena 24.0.12

- Pixel Seeds - ACTS in Athena
- Strip Seeds - ACTS in Athena
- All Seeds - ACTS in Athena
- All Seeds - Current Athena

ATLAS Simulation Preliminary
$\sqrt{s}$ = 14 TeV, HL-LHC
ITk Layout: 03-00-00
Truth p_T > 1 GeV
ACTS v29.1.0, Athena 24.0.12

- $t\bar{t}$, $\langle\mu\rangle$ = 200
- Single μ, p_T = 1 GeV
- Single μ, p_T = 100 GeV