Track reconstruction with ACTS in modern high-energy physics experiments

Gundolf Haase, Alexander J. Pfleger, Andreas Salzburger

22nd of September 2026

From Measurements to Tracks

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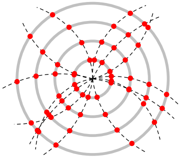

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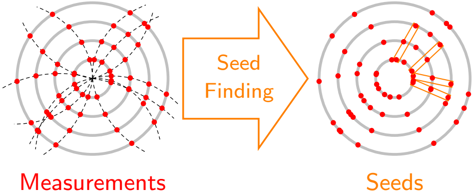

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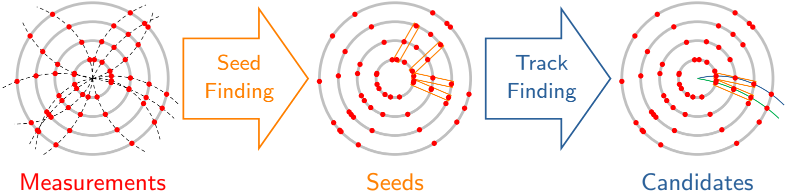

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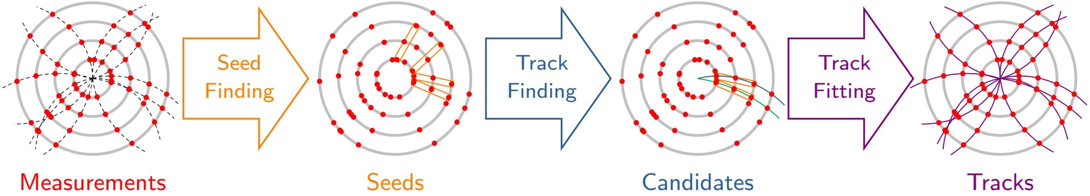
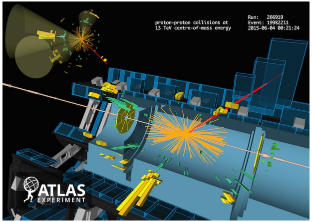
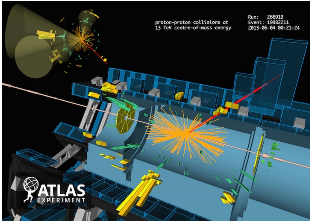




[1]

[1] ATLAS Collaboration

ATLAS with High Luminosity LHC



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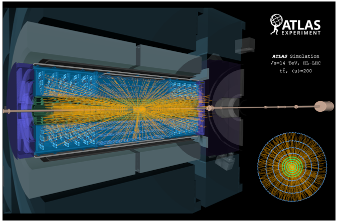

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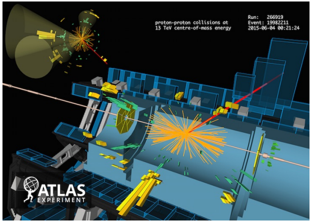

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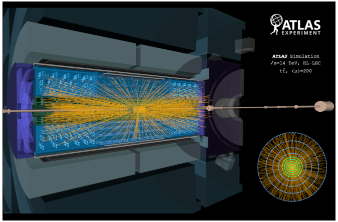

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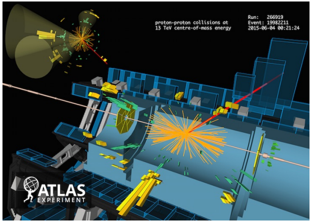

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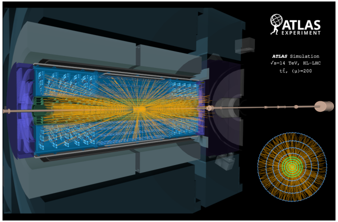

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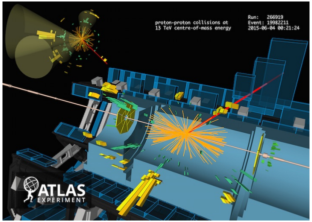

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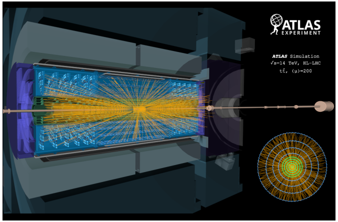

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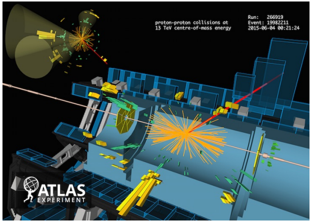

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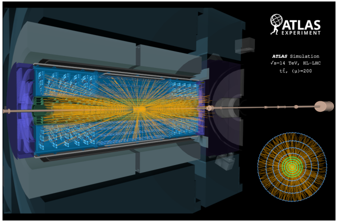

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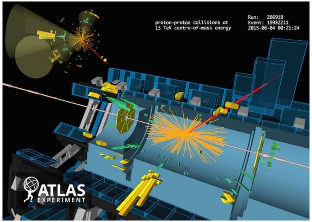

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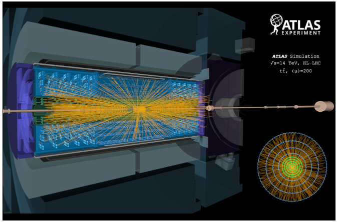

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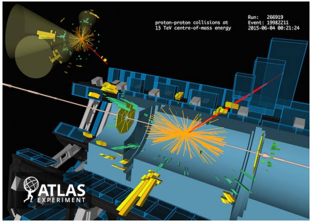

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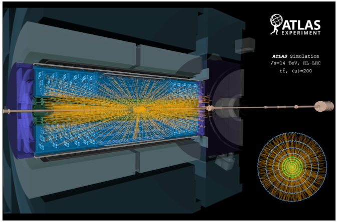

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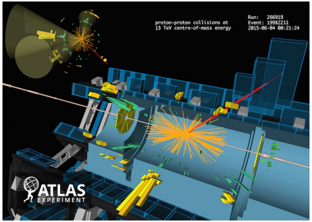

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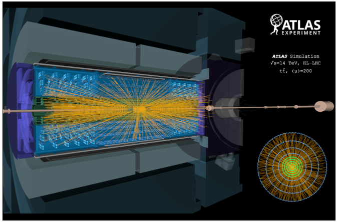

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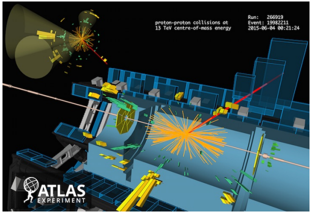

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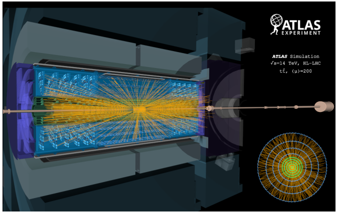

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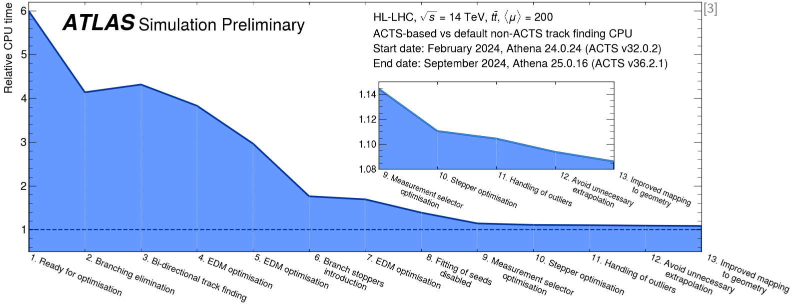

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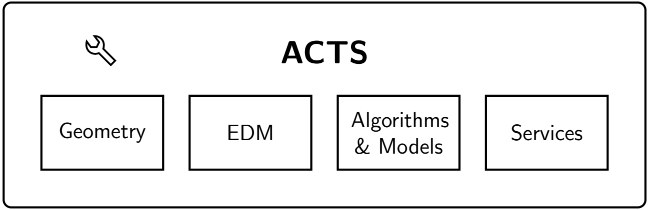
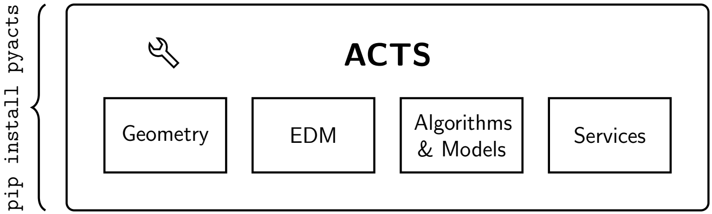
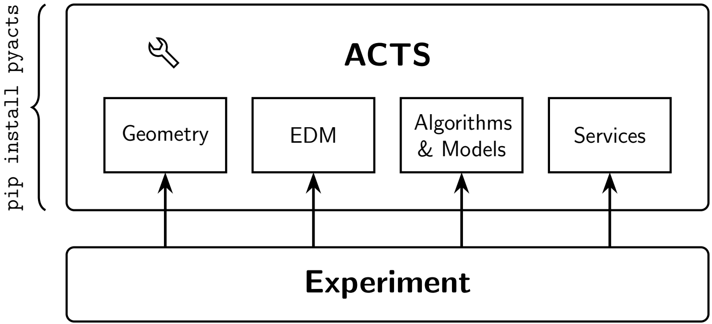
ACTS

ACTS – A Common Tracking Software





https://github.com/acts-project/acts/



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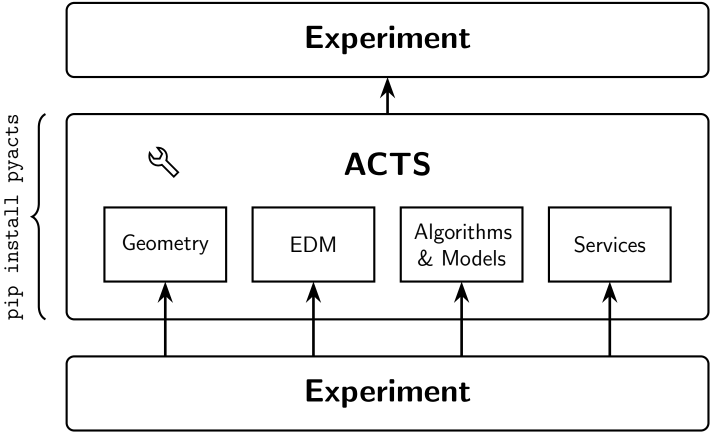

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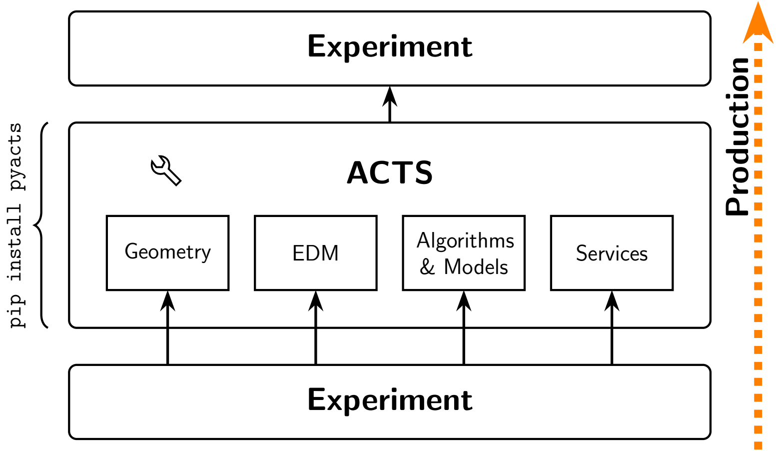

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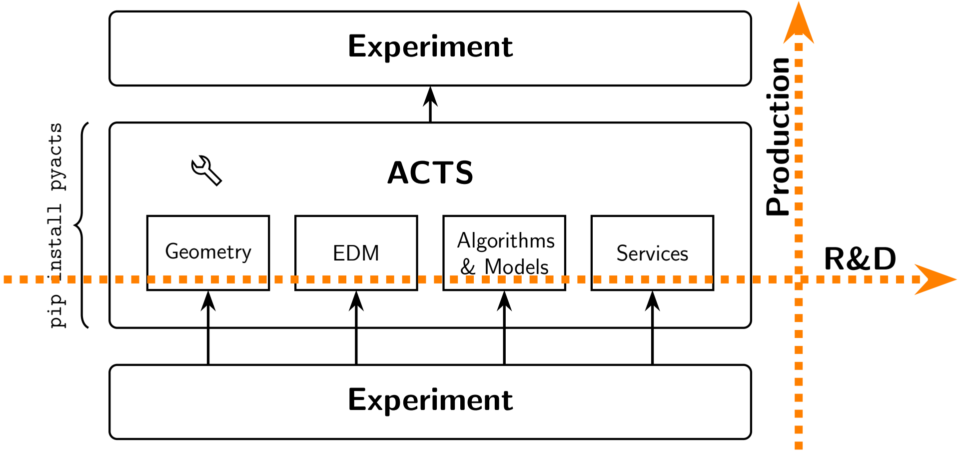

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Austrian contribution: Global χ^2 Fitter in ACTS

- Open Data Detector (ODD)
- 10^5 events, $|\eta| \leq 3$, $\phi \in [0, 2\pi)$
- $pT \in [1, 100]$ GeV/c, randomised charge (to reduce biases)

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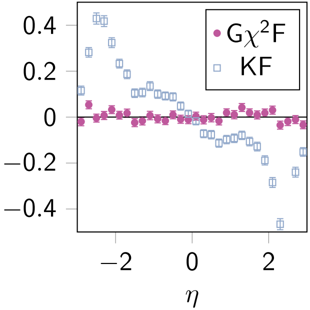

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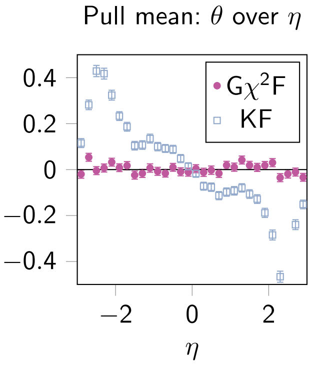

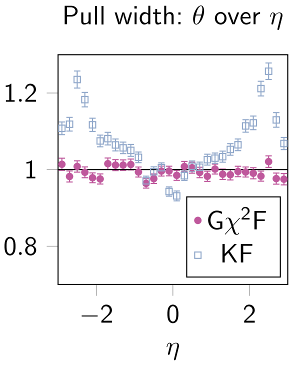

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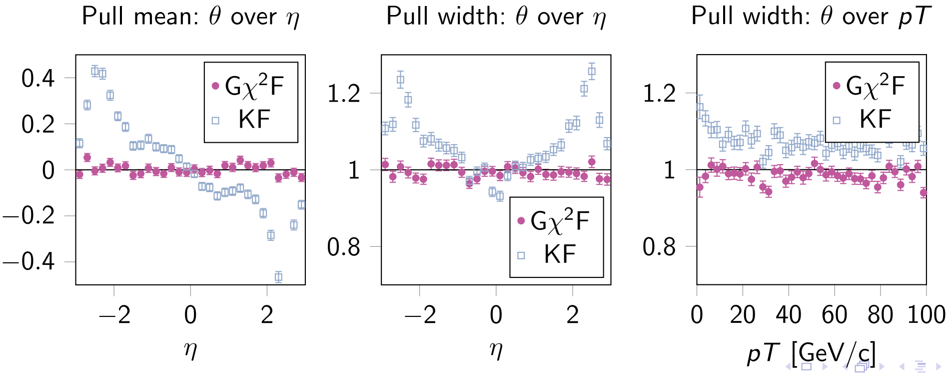

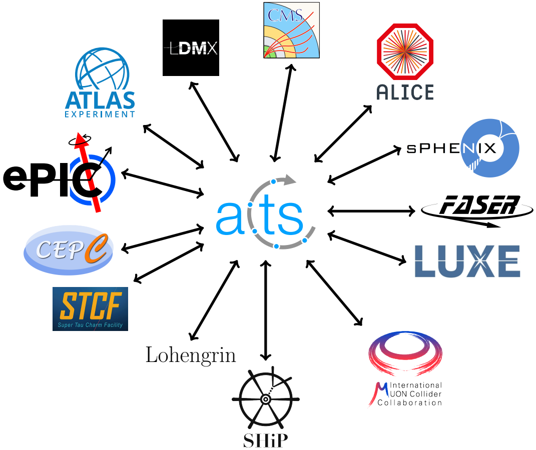

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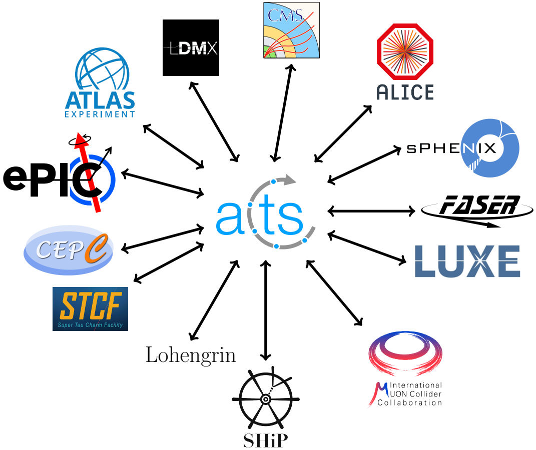
ACTS Across Detector Contexts – What Sharing Changes



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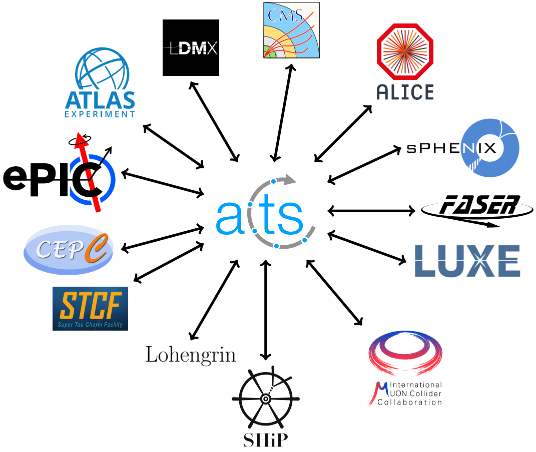

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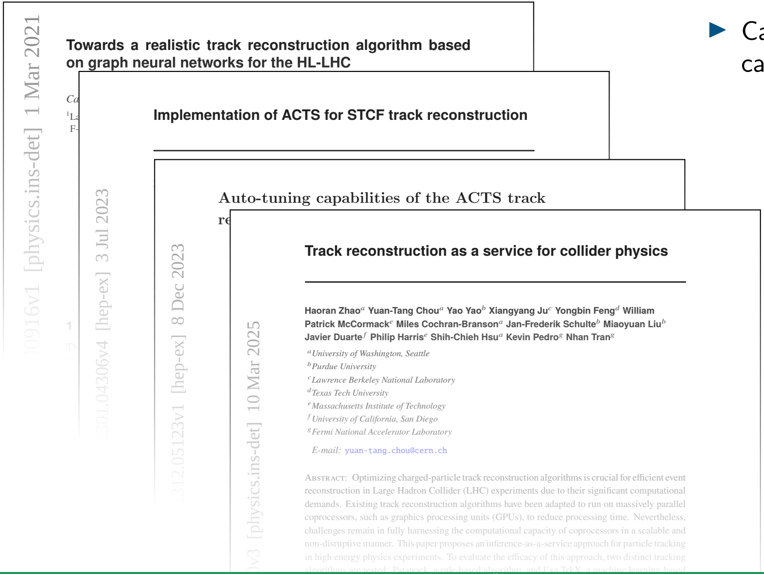
- Different detectors expose hidden assumptions
- Share development and maintenance

- Can machine learning reduce candidate combinations?

An R&D platform for future tracking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Track reconstruction as a service for collider physics

Haoran Zhao[a] Yuan-Tang Chou[a] Yao Yao[b] Xiangyang Ju[c] Yongbin Feng[d] William Patrick McCormack[e] Miles Cochran-Branson[a] Jan-Frederik Schulte[b] Miaoyuan Liu[b] Javier Duarte[f] Philip Harris[e] Shih-Chieh Hsu[a] Kevin Pedro[g] Nhan Tran[g]

[a] *University of Washington, Seattle*
[b] *Purdue University*
[c] *Lawrence Berkeley National Laboratory*
[d] *Texas Tech University*
[e] *Massachusetts Institute of Technology*
[f] *University of California, San Diego*
[g] *Fermi National Accelerator Laboratory*

E-mail: yuan-tang.chou@cern.ch

Abstract: Optimizing charged-particle track reconstruction algorithms is crucial for efficient event reconstruction in Large Hadron Collider (LHC) experiments due to their significant computational demands. Existing track reconstruction algorithms have been adapted to run on massively parallel coprocessors, such as graphics processing units (GPUs), to reduce processing time. Nevertheless, challenges remain in fully harnessing the computational capacity of coprocessors in a scalable and non-disruptive manner. This paper proposes an inference-as-a-service approach for particle tracking in high energy physics experiments. To evaluate the efficacy of this approach, two distinct tracking algorithms are tested: Patatrack, a rule-based algorithm, and Exa.TrkX, a machine learning-based

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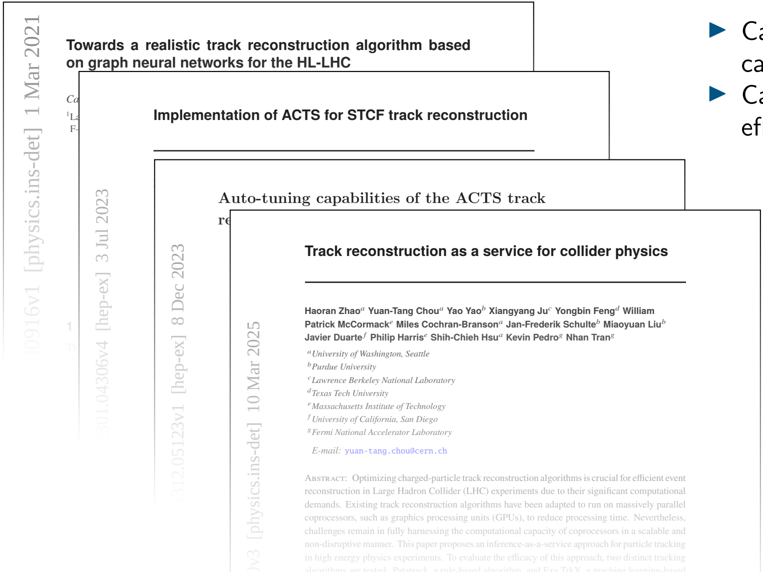

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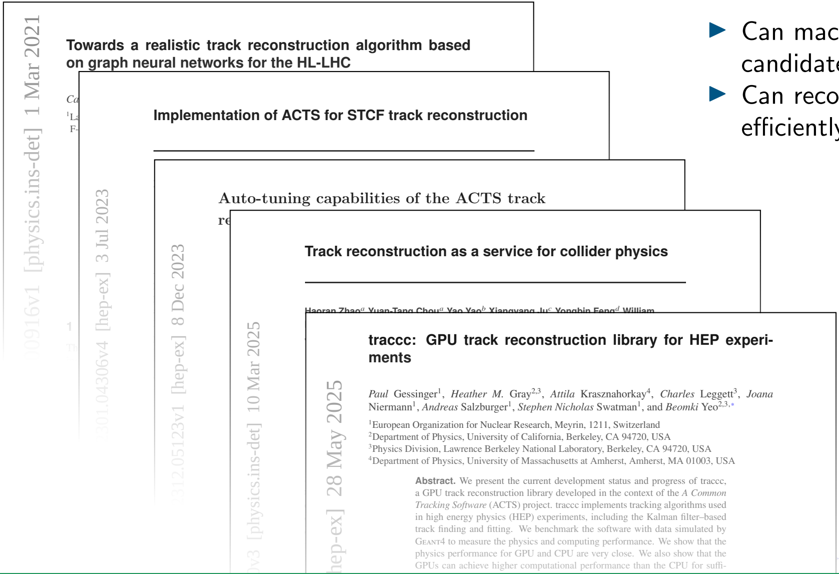

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28 May 2025 [hep-ex]

traccc: GPU track reconstruction library for HEP experiments

Paul Gessinger[1], *Heather M.* Gray[2,3], *Attila* Krasznahorkay[4], *Charles* Leggett[3], *Joana* Niermann[1], *Andreas* Salzburger[1], *Stephen Nicholas* Swatman[1], and *Beomki* Yeo[2,3,*]

[1]European Organization for Nuclear Research, Meyrin, 1211, Switzerland
[2]Department of Physics, University of California, Berkeley, CA 94720, USA
[3]Physics Division, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA
[4]Department of Physics, University of Massachusetts at Amherst, Amherst, MA 01003, USA

Abstract. We present the current development status and progress of traccc, a GPU track reconstruction library developed in the context of the *A Common Tracking Software* (ACTS) project. traccc implements tracking algorithms used in high energy physics (HEP) experiments, including the Kalman filter–based track finding and fitting. We benchmark the software with data simulated by GEANT4 to measure the physics and computing performance. We show that the physics performance for GPU and CPU are very close. We also show that the GPUs can achieve higher computational performance than the CPU for suffi-

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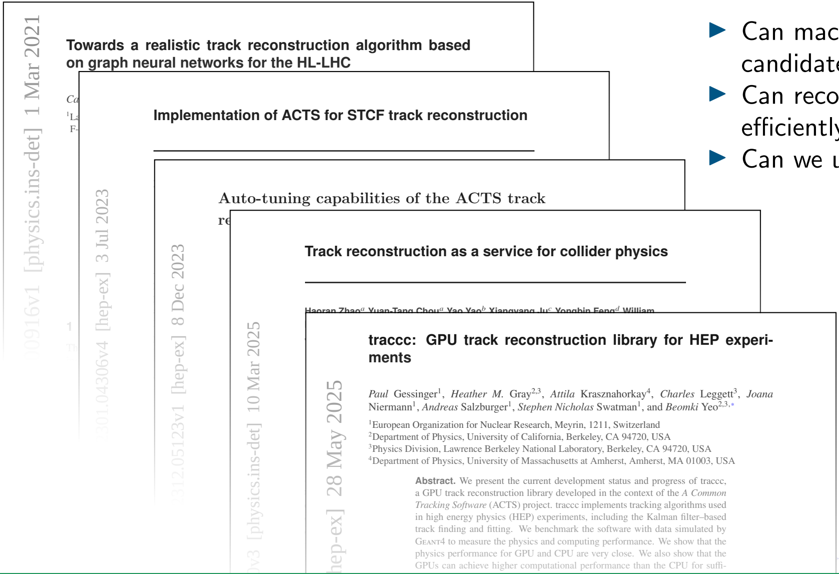

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- Can we use it in the future?

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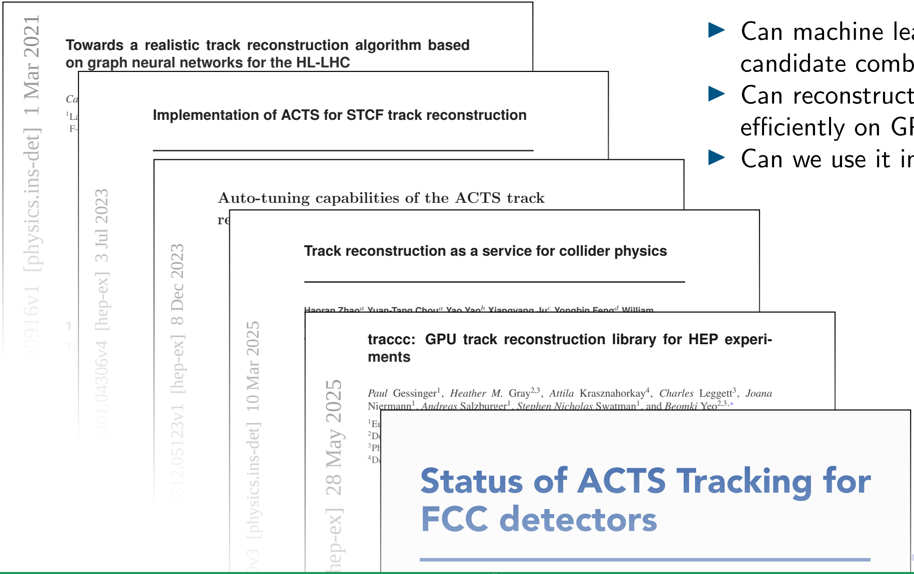

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Take-Home Message

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- R&D: machine learning, GPU tracking, future detectors, . . .

Extra Slides

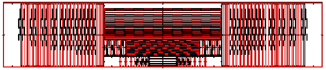
Enhancing CMS Passive Material Modeling in Track Reconstruction Using ACTS

Lorenzo Damenti
ACTS Workshop, 20-24 April 2026, NIKHEF

CMS Tracking Geometry in ACTS

- All sensitive surfaces from a *TrackerGeometry* in CMSSW are selected and converted into ACTS *DetectorElements (DetEls)*
- **Note:** $detID_{CMSSW} \leftrightarrow detID_{ACTS}$
- DetEls are organized in tracking layers; **Note:** not always tracking layers correspond to physical layers

- Layers are arranged into volumes following a hierarchical structure
- **Full CMS blueprint:**

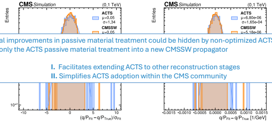


- **Open Points:**
  - I. Is the number of material layers too high?
  - II. Is the layers placement correct?
  - III. Is the binning appropriate?

  → **Geometry Optimization**

Proof of Concept

- First test: Perform track refits on simulated muons ($p_t = 100GeV$)
- Purpose: Validate geometry built and identify major showstoppers
- **Note:** Test performed using all algorithms from ACTS (i.e. propagation and refit)
- Results show a good agreement between ACTS and CMSSW



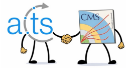
Problem: Potential improvements in passive material treatment could be hidden by non-optimized ACTS algorithms for CMS
Solution: Import only the ACTS passive material treatment into a new CMSSW propagator
Advantages:

- **I.** Facilitates extending ACTS to other reconstruction stages
- **II.** Simplifies ACTS adoption within the CMS community

- **Next Step:** decrease the p_t to probe passive material effects? Yes, but…

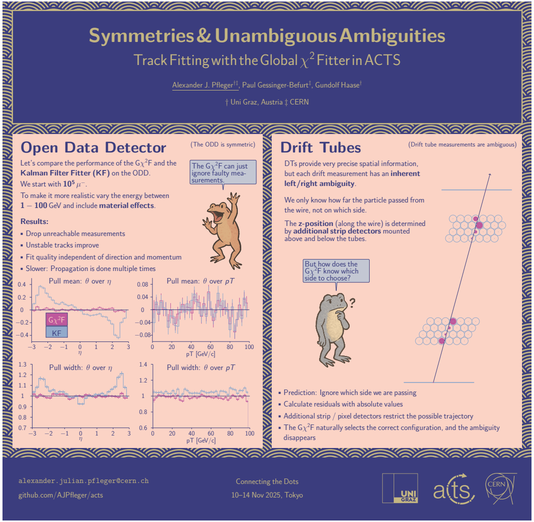
Summary and Next Steps

- Description of passive material effects in CMSSW is suboptimal → verify if it can be improved by importing the passive material treatment approach adopted by ACTS defining a new ACTS propagator within the CMS Data Analysis Framework
- Build (and validate) the CMS Geometry within ACTS ✅
- Validate material maps used to decorate material layers ✅
- Write a new CMSSW propagator using ACTS ✅
- Validate the new propagator:
  - I. Compare refit performance (pulls and residuals distributions) ***Ongoing***
  - II. Compare Track Efficiency (Using ACTS propagator in all track reco steps)
- Reconstruction of $K_S^0 \to \pi^+\pi^-$ decays and comparison between ACTS and CMSSW



https://indico.cern.ch/event/1577742/contributions/7005748/

- Full algorithm
- Already explored by experiments
- Austrian Doctoral Student Programme
- PhD at Uni Graz at CERN



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