# **Recent Developments in ACTS**

Paul Gessinger CERN 2021-11-10 - International Workshop on the High Energy Circular Electron Positron Collider

# Track reconstruction<sup>1</sup> in a nutshell



<sup>1</sup>Approach used by ATLAS, others

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2021-11-10 - CEPC Workshop



Experiment-independent toolkit for track reconstruction applications









#### Goals:

- Provide established algorithms in a modern package
- Provide testbed for R&D activities including new algorithms, machine learning, heterogeneous computing

Experiment-independent toolkit for track reconstruction applications

# Growing development community

- Development on GitHub since March 2020
- Number of contributors growing, participation in main meeting and ancillary meetings strong
- Active discussions, cross-experiment input enables more careful design



Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented in modern C++  Construction in (high energy) physics experiments implemented i	- @-
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gagnonig feat: implement clusterization/hit merging in DigitizationAl im • fbb6888 2 hours ago (36,005 commits (charged) particle track reconstruction in (high energing) in the second s	lkit for ay)

# **Continuous integration**

- Unit style tests and integration style tests
  - Exercises about 50% of code branches
- Test on variety of platforms and compilers:
  - Ubuntu, CentOS7/8, macOS
- Automated documentation build: acts.readthedocs.org
- Monitor build performance over time
- Will add other metrics to track

0	macos	41m 12s	
ø	cuda	20m 53s	
ø	sycl	18m 44s	
ø	docs	11m 2s	
Matrix: linux			
0	linux (centos7-lcg97a.	44m 58s	
Ø	linux (centos7-lcg98	. 44m 28s	
ø	linux (ubuntu2004)	42m 9s	

## **Integration model**

- ACTS provides individual components
- Experiments assemble components into reconstruction chain
- Easy integration into logging, dedicated structs for configuration
- ACTS ships with a comprehensive set of examples demonstrating how to achieve this

# Evaluation and/or deployment by multiple experiments



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# **ATLAS integration**

Run 3

 ACTS vertexing used as default for production in Run 3



 Run 3 geometry (incl. Transition Radiation Tracker) still work in progress

#### Run 4 (ITk)



- Strong push for ACTS components in ITk
- Integration effort ramping up
- Current focus: Event Data Model for seeding, track finding + fitting

# **Current status of ACTS core**

# Seed finding

- Triplet finding for initial pattern-recognition on an event
- Space points are filled into grid in  $(r, \phi)$
- Combinations are built as doublets and then triplets
  - Attempt to reject as early as possible based on crude estimate of momentum, direction, curvature, ...
- Configuration is highly dependent on detector / geometry, needs to be tuned to give good performance





# **Drift chamber and TPC reco**

- Context: ACTS is mostly developed by ATLAS members
  - some focus on wire detectors (ATLAS TRT)
  - no focus on TPCs
- TRT reconstruction: preliminary version exists, not optimized, not well-tested
- TPC reconstruction: complicated by ACTS not supporting 3D measurements (yet: issue)
  - Workaround used by sPHENIX: approximate by number of flat surfaces
- We're very open to contributions in these directions, get in touch if you're interested!



# **Compute performance**

- Recall: designed with thread-safety as core goal to fully utilize many-core CPUs
  - High concurrency at least as important as efficient single-threaded algorithms
- Concurrency works, can handle concurrent geometry alignment efficiently





# ACTS performance (based on TrackML detector)



# **Recent developments**

#### **Baseline for alignment infrastructure**

- Why alignment?
  - $\Rightarrow$  Misalignment of sensors needs to be **corrected** for highest-precision
- First version of a alignment calculation recently introduced
- Based on the Kalman Filter
- Will serve as baseline to provide a production-ready alignment solution

alignment of individual sensors



## Orthogonal range seed finder

- New approach to *classical* seed finding
- Used kd-trees to partition and select space points for seed search
- Promising physics performance, still being investigated
- Potential for 6-10x speedup w.r.t. to *classical* implementation in HL-LHC regime



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# ACTS paper nearing the finish line

- Documents and discusses design choices, developments, conclusions drawn and lessons learned
- Contains comprehensive performance measurements for key tracking components
- Preprint at 2106.13593
- Submitted to CSBS

Preprint submitted to Computing and Software for Big Science manuscript No. (will be inserted by the editor)

#### A Common Tracking Software Project

Xiaocong Ai · Corentin Allaire · Noemi Calace · Angéla Czirkos · Markus Elsing · Irina Ene · Ralf Farkas · Louis-Guillaume Gagnon · Rocky Garg · Paul Gessinger · Hadrien Grasland · Heather M. Grav · Christian Gumpert · Julia Hrdinka · Benjamin Huth · Moritz Kjehn · Fabian Klimpel · Bernadette Kolbinger · Attila Krasznahorkav · Robert Langenberg : Charles Leggett : Georgiana Mania : Edward Moyse : Joana Niermann - Josenh D. Osborn - David Rousseau - Andreas Salzburger · Bastian Schlag · Lauren Tompkins · Tomohiro Yamazaki · Beomki Yeo · Jin Zhang Iun June 28, 2021 10 Abstract The reconstruction of the trajectories of Corresponding author. E-mail: andreas.salzburger@cern.ch charged particles, or track reconstruction, is a key compatational challenge for particle and nuclear physics. Angella Criticos Fötels Lorind University 1053 Budanest Hunsars experiments. While the tuning of track reconstruction algorithms can depend strongly on details of the detec-Desting Soblar Institut für Physik, Johannes Gutenberg-Universität tor geometry, the algorithms currently in use by experi-Mainz, 55128 Mainz, Germany ments share many common features. At the same time, the intense environment of the High-Luminosity LHC Xiaocong Al - Georgiana Mania Deutsches Elektronen Synchrotron, 22607 Hamburg, accelerator and other future experiments is expected to put even greater computational stress on track re-Rocky Garg - Lauren Tompkine construction software, motivating the development of Stanford University, CA 94305, Stanford, USA more performant algorithms. We present here A Com-Corentin Allaire - Normi Colace - Markon Elaine - Paul mon Tracking Software (ACTS) toolkit, which draws Gessinger - Moritz Kiehn - Fabian Klimpel - Bernadette Kolon the experience with track reconstruction algorithms. binner - Attila Kraemahoekeer - Joana Niermann - Andreas in the ATLAS experiment and presents them in an Salahummer . Dastion Schlor 5 experiment-independent and framework-independent 3 CERN, 1211, Geneva, Switzerland toolkit. It provides a set of high-level track recon-Hadrien Grasland - David Rousseau Université Paris-Saclay, CNRS/IN2P3, LICLab. struction tools which are agnostic to the details of the 91405 Orsay, France detection technologies and magnetic field configuration and tested for strict thread-safety to support multi-Jin Zhang 90 Institute of High Energy Physics, Chinese Academy threaded event processing. We discuss the conceptual of Sciences 100 039, Beijing, China design and technical implementation of ACTS, selected Irina Ene - Louis-Guillaume Gagnon - Heather M. Gray - To applications and performance of ACTS, and the lessons mohiro Yamazaki - Beomki Yeo Department of Physics, University of California, CA 94720 Berkeley USA arXi burg, Germany Ioronh D. Ooloom Oak Ridge National Laboratory, TN 37831, Oak Heather M. Gray - Charles Legrett Ridge, USA Lawrence Berkeley National Laboratory, CA 94720. Berkeley, USA Robert Langenberg - Edward Movie University of Massachussets, MA 01003, Amherst. **Renjamin Huth** 

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# **Summary & conclusion**

- ACTS is expanding and improving in all directions!
  - Working closely with other efforts in HEP software efforts (e.g. DD4hep), will integrate more tightly (Gaudi, key4hep)
- Full track reconstruction chain established: from hits to tracks to vertices
  - ► Would **welcome contributions** to further develop drift chamber and TPC reconstruction
- Experiment evaluation/integrations are numerous
- ACTS paper (2106.13593) submitted, published soon

