BERKELEY LAB

Geometry Description

Vakho Tsulaia (LBNL)

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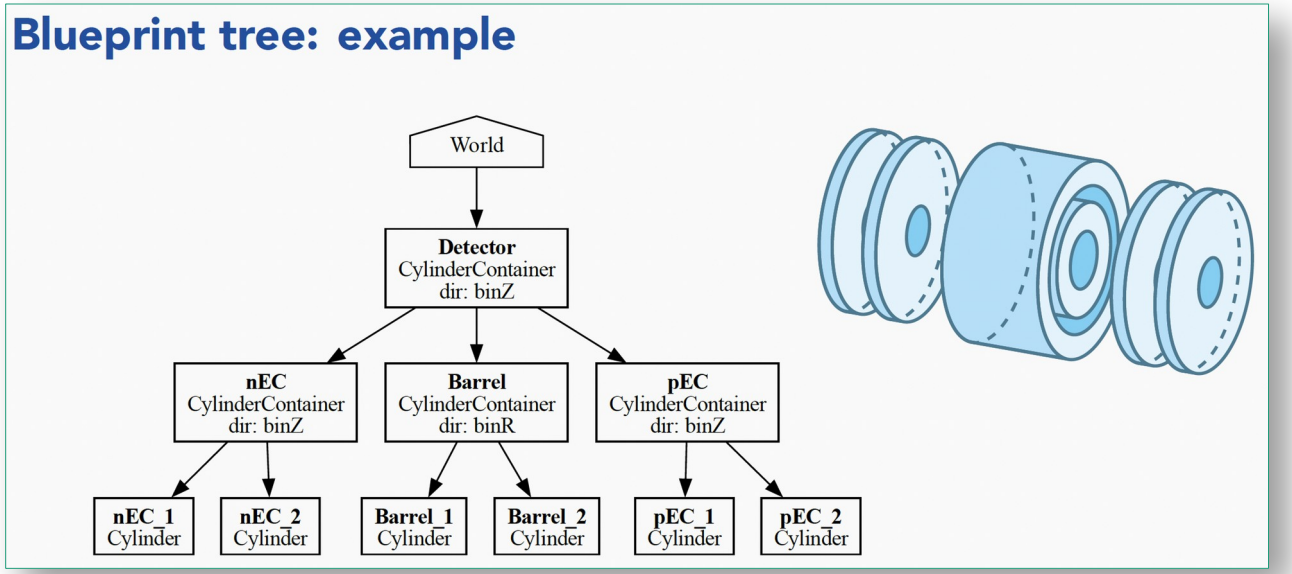
Introduction

- We started to look into the conversion of detector geometry description from the DD4hep format into ACTS Gen3 tracking geometry in Summer 2025
  - More details about the ACTS Gen3 tracking geometry can be found in the talk presented by Paul Gessinger at the Workshop on ACTS Tracking for Nuclear Physics, LBNL, May 2025
- As a first step in this activity, we developed a unit test demonstrating how to translate DD4hep detector geometry into ACTS Gen3
  - Merged with the ACTS main branch in September 2025
- The work on translating the DD4hep-based description of the FCC-hh tracker geometry into ACTS Gen3 started during the ACTS Geometry hackathon at CERN in December 2025

ACTS Gen3 tracking geometry

- Central concept: **Blueprint Tree**
- Nodes can represent **subsystems, tracker layers, etc.**
- Build phases are propagated down the tree. Nodes can make decisions based on their children (e.g., synchronize volume sizes, register volume connections via portals)



- The main responsibility of the user code is to construct the blueprint tree
  - Implement the logic based on the *source* of the geometry description (e.g., *DD4hep*, *GeoModel*)
  - After that, pass the blueprint tree to the ACTS API to construct the tracking geometry

FCC-hh tracker studies: Before the ACTS hackathon

- **Mehrunnisa Mirza** from Queen Mary University of London had been working on the FCC-hh tracking with ACTS
- She presented first results of her research at the ACTS Developers Meeting in October 2025
- For her studies, Mehrunnisa adapted the code from the FCCDetectors repository and some ACTS examples:
  - Translates DD4hep description of the tracker into ACTS **Gen1**
  - Uses the resulting description for tracking studies with ACTS
    - Material studies
    - Tracking efficiency and Impact resolution for Single Particles

FCC-hh tracker work: After the ACTS hackathon

- A first, simplified version (translating only a small part of the detector) was implemented during the hackathon
- In early 2026, Paul Gessinger made several iterations on the DD4hep to ACTS Gen3 translation API
  - The goal was to optimize the API and make it simpler for use by clients
- Eventually the API was merged with the ACTS main branch in April 2025, and became part of the ACTS releases since **v46.3.0**
- Using this version of the API, we implemented the translation for the entire tracker geometry from DD4hep into ACTS Gen3
- The translation was verified at runtime by running some simple visualization checks. More detailed testing and validation are yet to be performed

Code availability

- The updated DD4hep description (XML description and C++ plugin code) of the FCC-hh tracker
  - In late May 2026, a PR was opened on the k4geo repository for storing the version of the FCC-hh tracker geometry description used by our tests
  - The description did not pass the geometry overlap checks
  - Addressing these issues required some expertise in the geometry of the tracker
    - The project was postponed until September due to unavailability of person power to work on it
- The translator code
  - The plan is to merge the translator code with the k4ActsTracking repository after we make the DD4hep description available in the **k4geo** repository

FCC-hh tracker work: Next steps

- Make the description and the translator available in the “official” repositories
- Run initial testing and validation to confirm the sanity of the description
- Pass it over to the relevant groups for further studies

Further work on the Geometry Description

- In the longer term, we plan to focus on the DD4hep Detector Description framework
  - After some discussions with the lead developers of Key4hep: Brieuc Francois and Juan Miguel Carceller

- In particular, leveraging our expertise in detector description alignment under changing conditions, we plan to
  - Study the alignment infrastructure provided by DD4hep
  - Develop mechanisms to supply conditions data to the detector geometry description
  - Adjust geometry as conditions change

Alternative Geometry Description Framework

- DD4hep is often referred to as a “de facto standard for detector geometry description in HEP experiments”
  - Used by CMS, LHCb, and future concepts
- However, ATLAS has successfully used GeoModel as the detector geometry description engine for over two decades
  - No plans to switch over to DD4hep
- Recently, the SHiP experiment did a careful evaluation of the detector geometry frameworks (DD4hep and GeoModel being the main contenders), and picked GeoModel as the experiment detector description engine
- The GeoModel core team is more than happy to provide further details and assistance to the developers/teams/experiments who are interested in giving the toolkit a try

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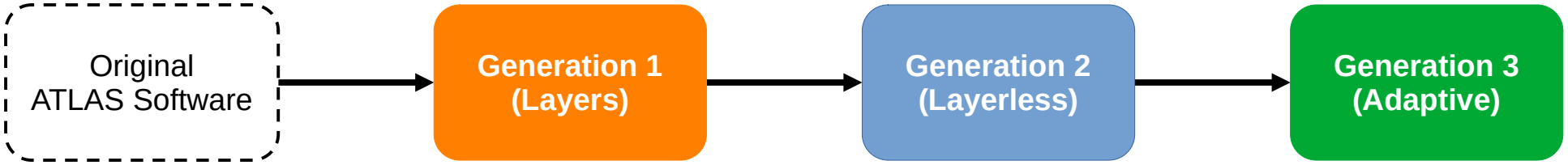
Geometry Model Evolution



- **Original geometry model**: layers are a first-class concept
  - Restricts flexibility for other layouts
  - Adds additional complexity to navigation

- **2nd Generation**: experimental geometry model
  - Drops layers in favor of layer-volumes
  - Validates approach of registering local navigation inside volumes
  - Demonstrates conversion to detray GPU geometry model for use with traccc

- **3rd Generation**: combination of both
  - Layer-volumes with local navigation policies
  - Rewrote geometry construction from the ground up
  - Extensible, composable and flexible