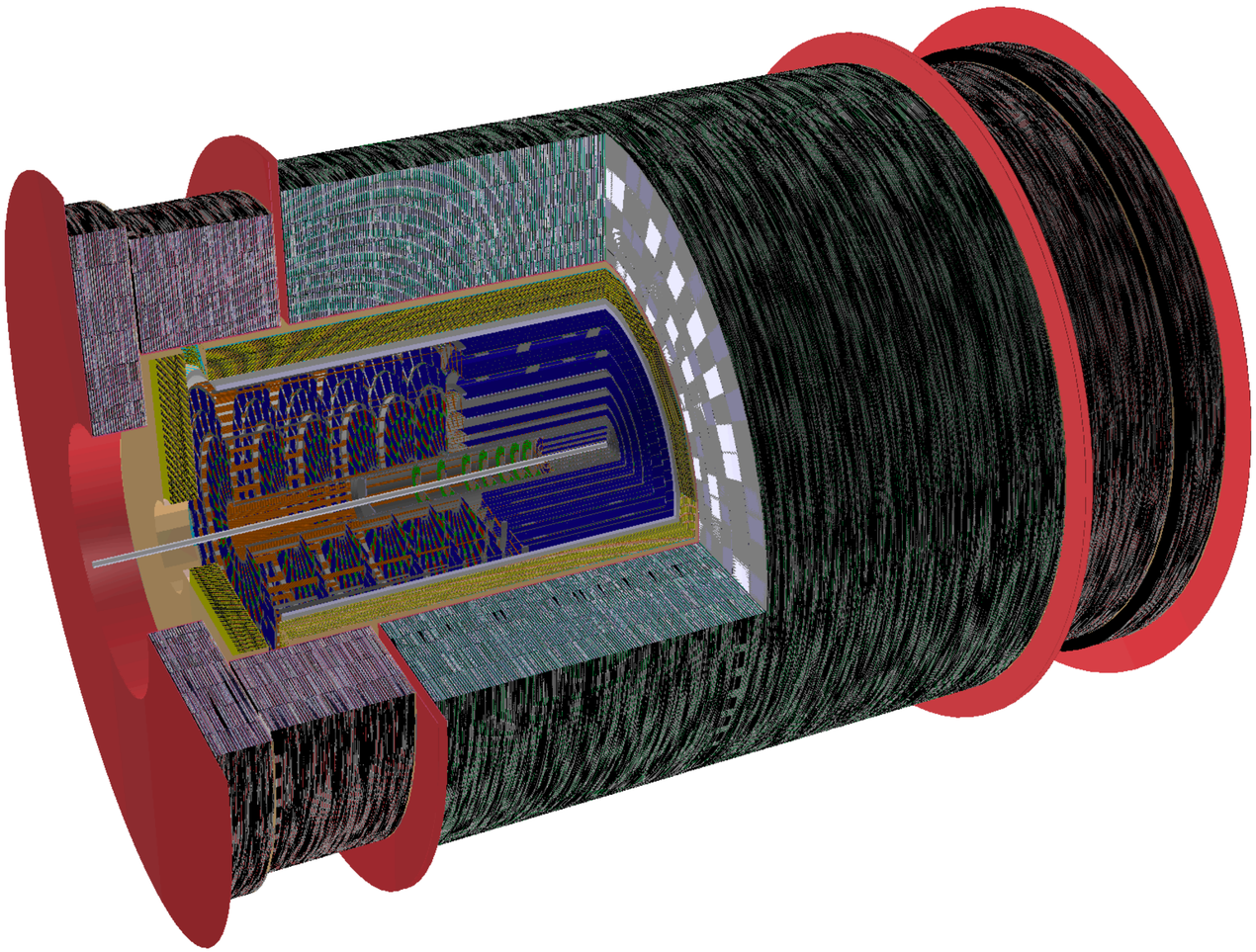
EP R&D

Universität Regensburg



Norfolk, Virginia, USA • **May 8-12, 2023**

CHEP 2023

Computing in High Energy & Nuclear Physics

The Open Data Detector Project

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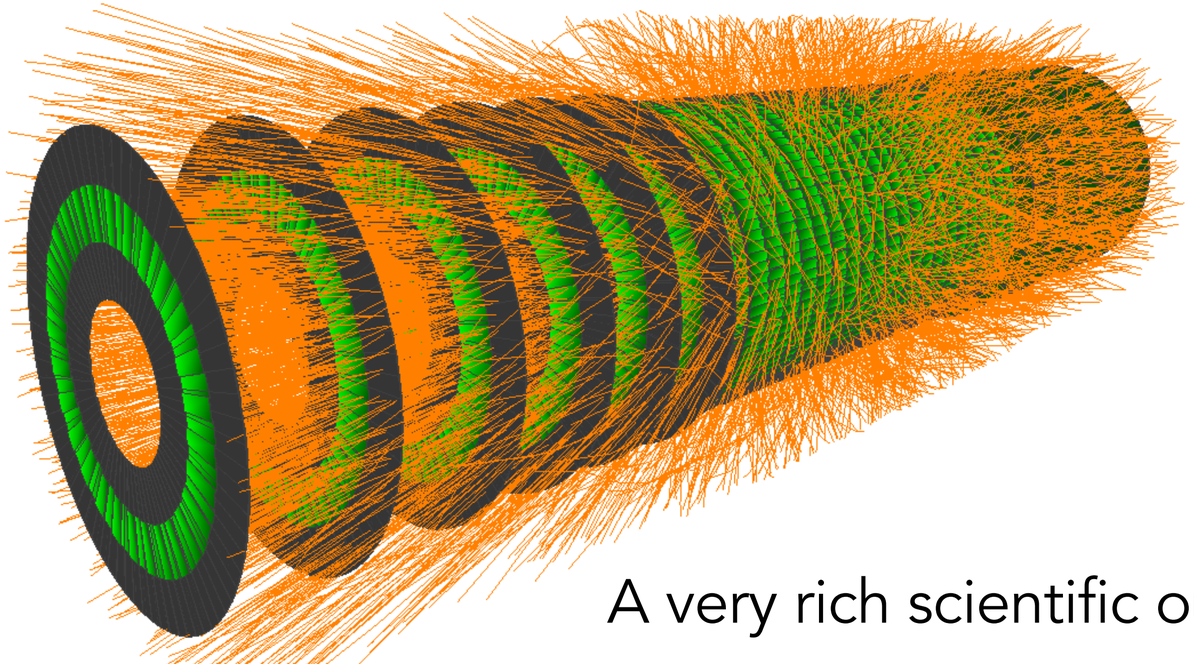
[1]*CERN*, [2]*University of Regensburg*, [3]*TU Vienna*

The History



Tracking machine learning challenge: phase 1 | phase 2 (2018)

Definition of an HL-LHC like detector

- production of training/test dataset
- definition of .csv data format
- definition of a figure of merit

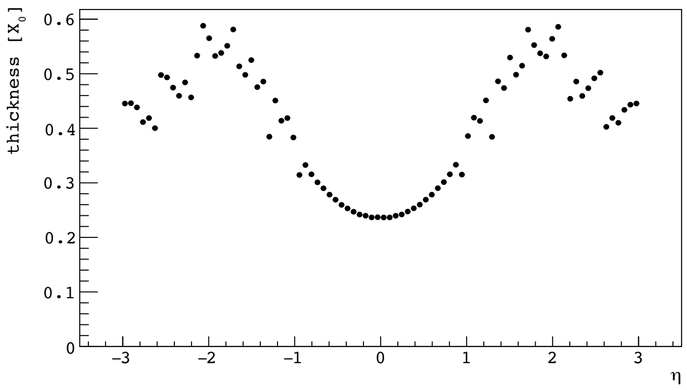
A very rich scientific outcome - and a dataset that is **still** in use

… and counting

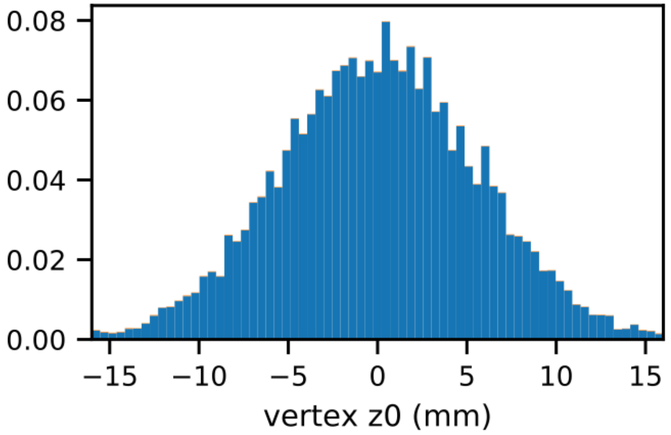
(Numerical) track reconstruction software, metric learning, Graph Neural Network, Quantum Annealing, Quantum Machine Learning

The TrackML Shortcomings

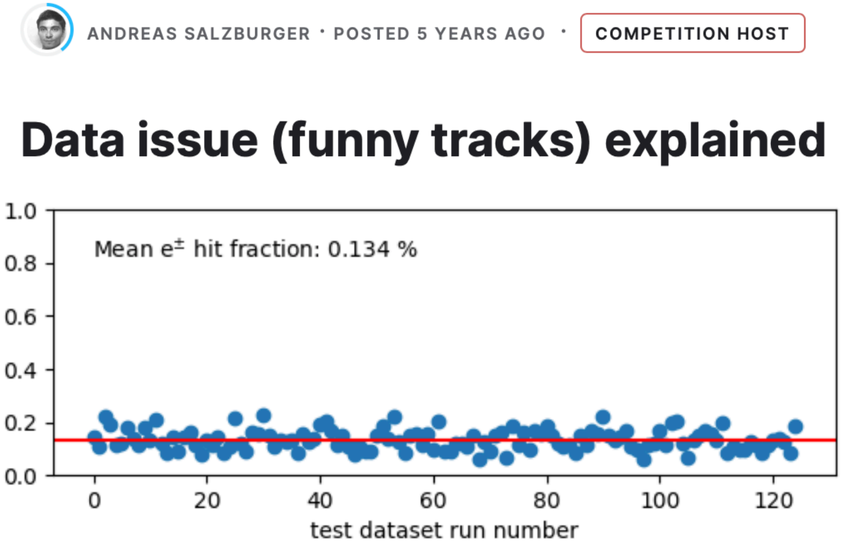
TrackML dataset was restricted to a **very optimistic Inner Tracking Detector** model, based on **fast simulation**, and had a **few features**.



Too optimistic material estimates

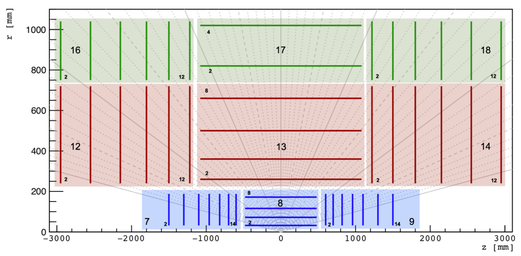


Too narrow beam spot for a realistic (HL-)LHC like experiment



Loopers in the dataset,
wrong scattering formula for electrons

The Evolution: ODD Tracking System

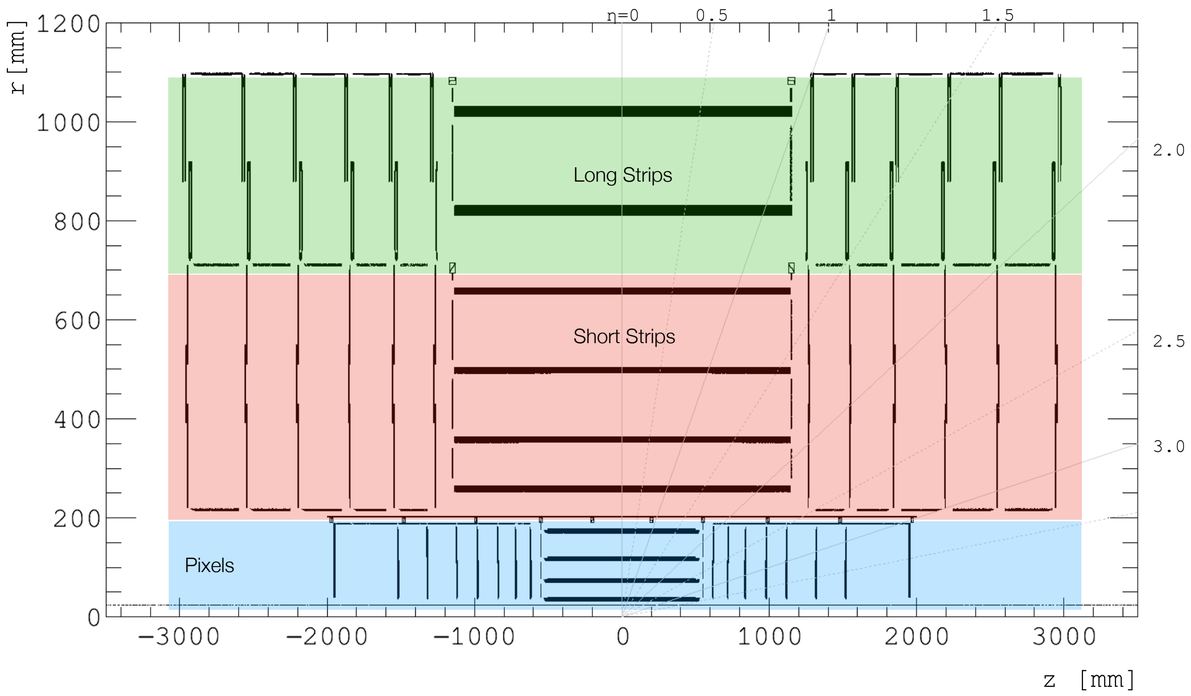


TrackML detector re-implemented using DD4hep and keeping the main features identical:

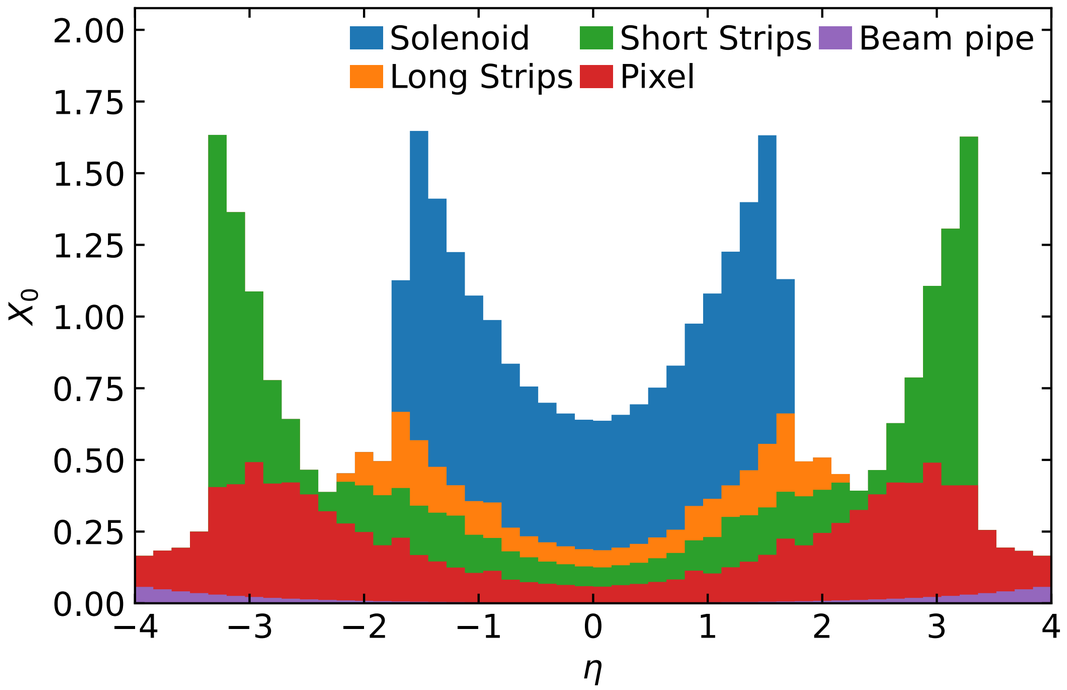
Innermost Pixel System
Short Strip System
Long Strip System

hermetic min 12 hit system, Silicon only

$|\eta| < 3$

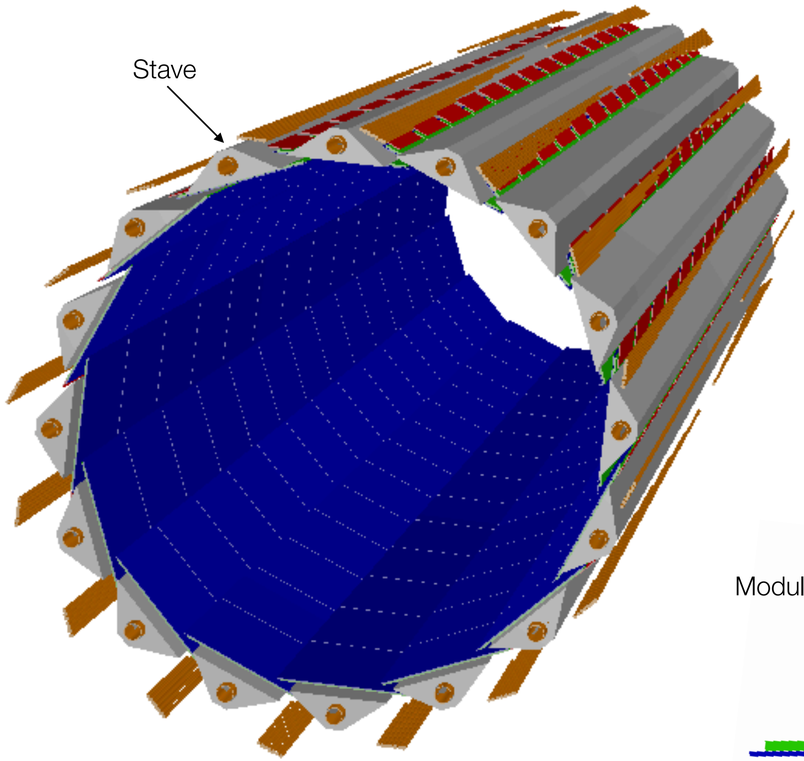


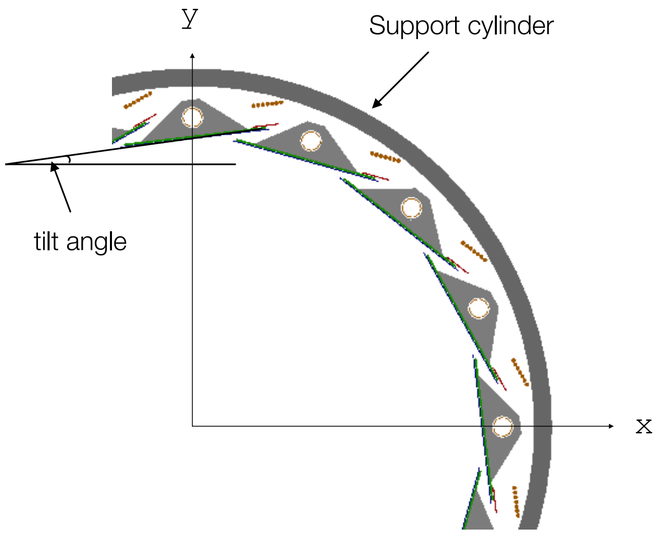
Geant4 hit locations of the ODD detector.

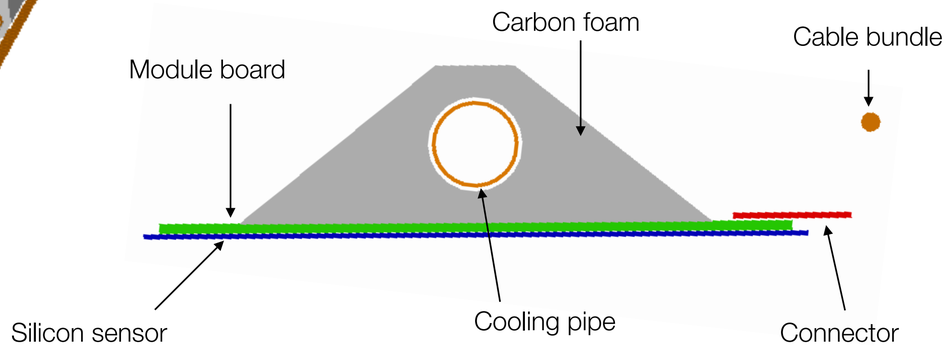


Material budget versus pseudo-rapidity.

The Level of Detail







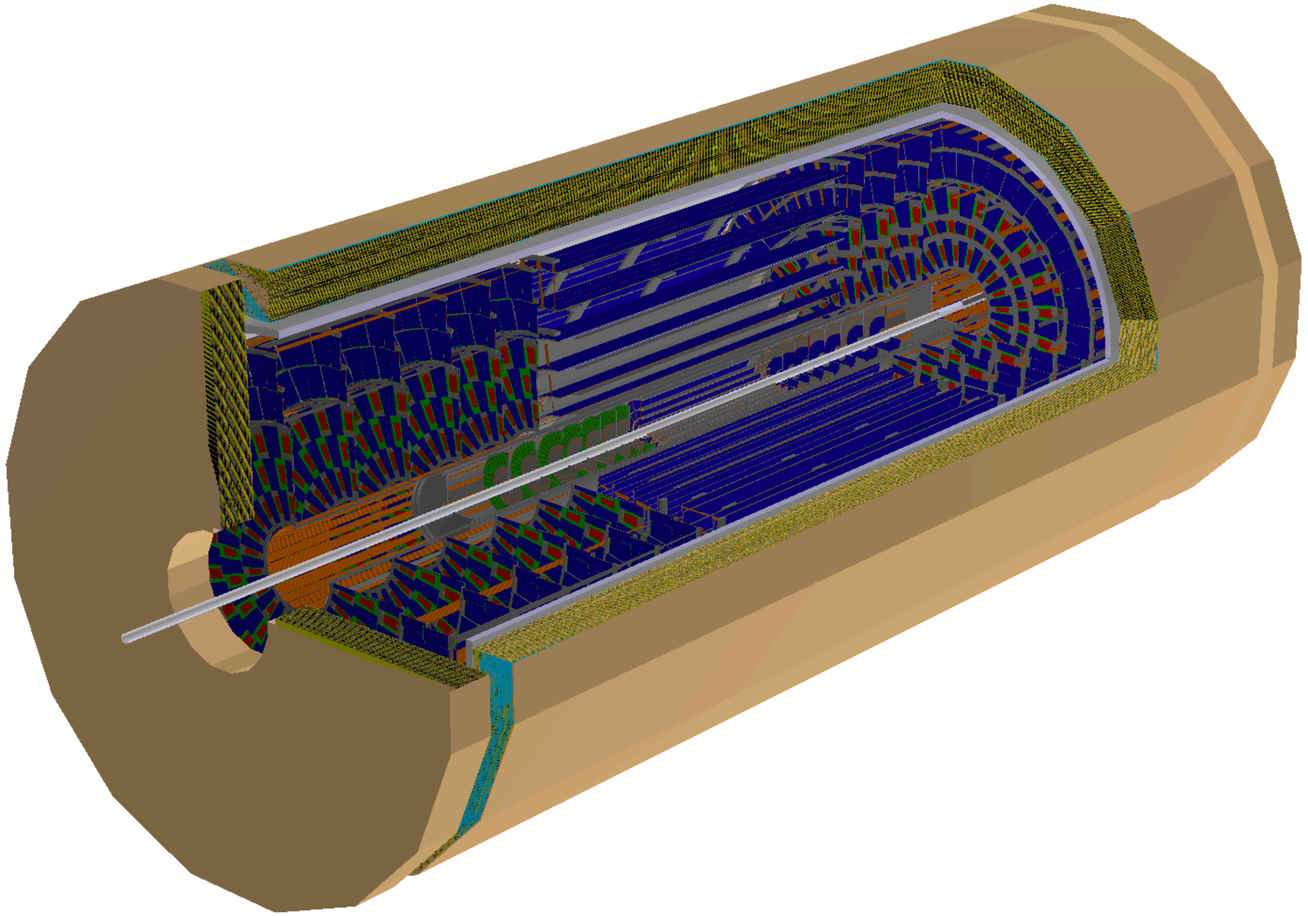
The **ODD** aims to describe a detector at a **similar level of detail** as current LHC experiments are described.

Support algorithmic, software computing R&D with realistic detector geometry, even future contextual data (alignment, conditions) are possible.

Innermost Pixel detector barrel, stave and module details of the ODD Tracker. Displayed with DD4hep/ROOT.

[full detector details]

The Detector: EM Calorimeter

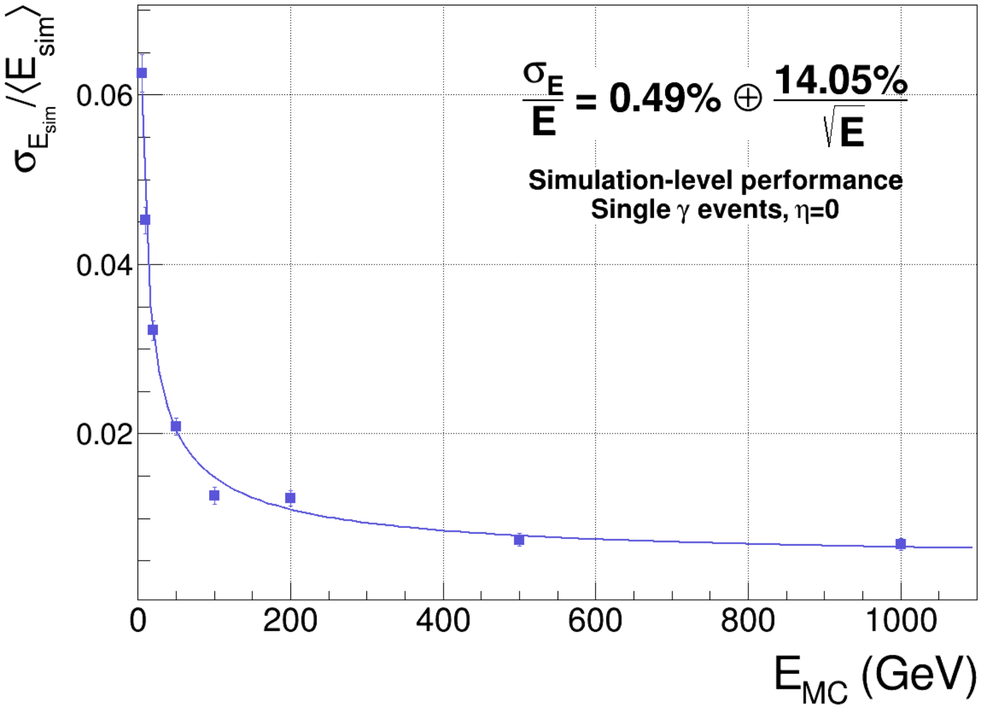


ODD Electromagnetic Calorimeter option

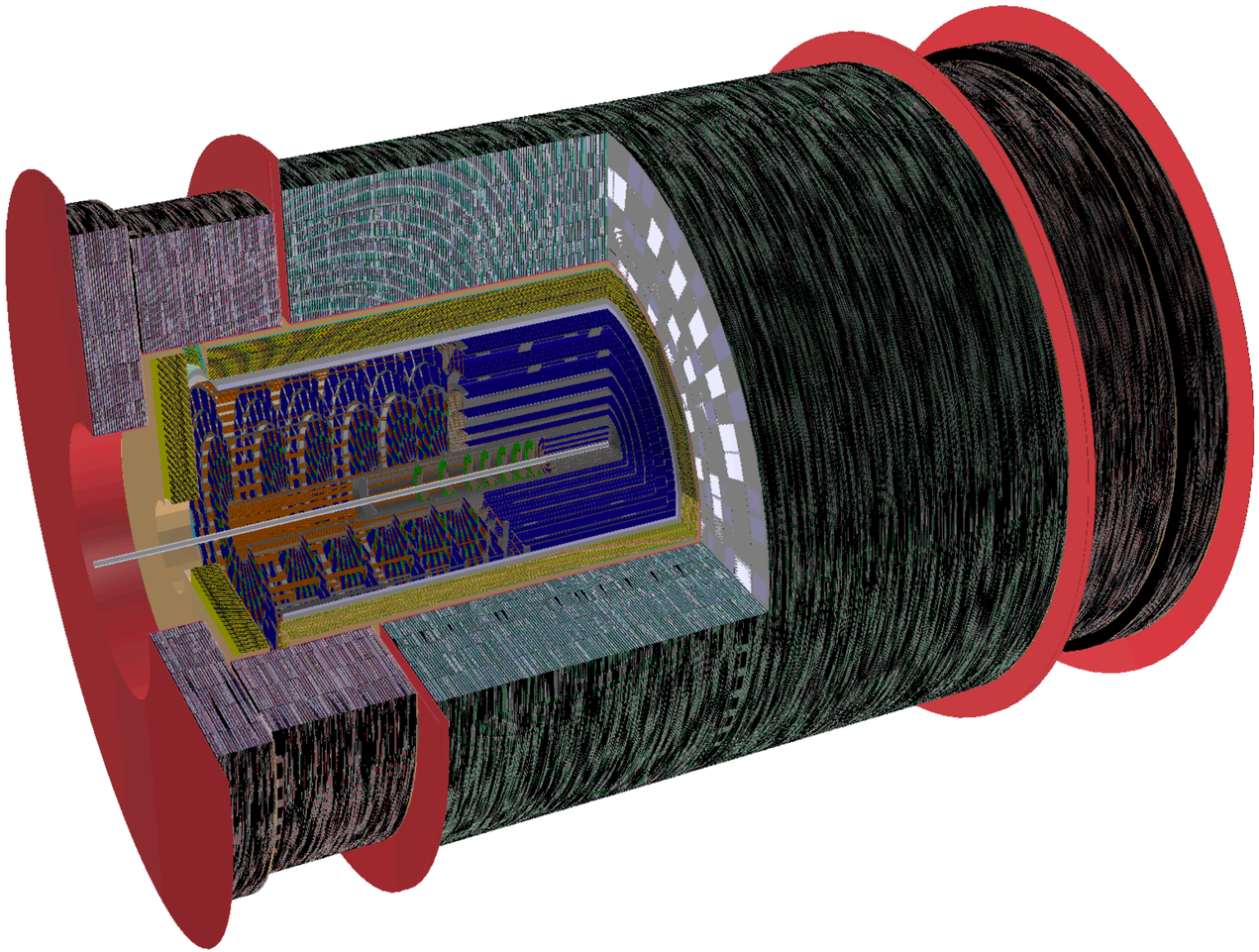
Recently added **ODD** Electromagnetic Calorimeter

- high granularity Silicon-Tungsten sampling calorimeter

[full detector details]



The Detector Expansion



Possible expansion with the FCC-hh TileCalorimeter (derivate of ATLAS Tile Calorimeter).

Facilitated by DD4hep detector description and envelope definition.

Another option in study:

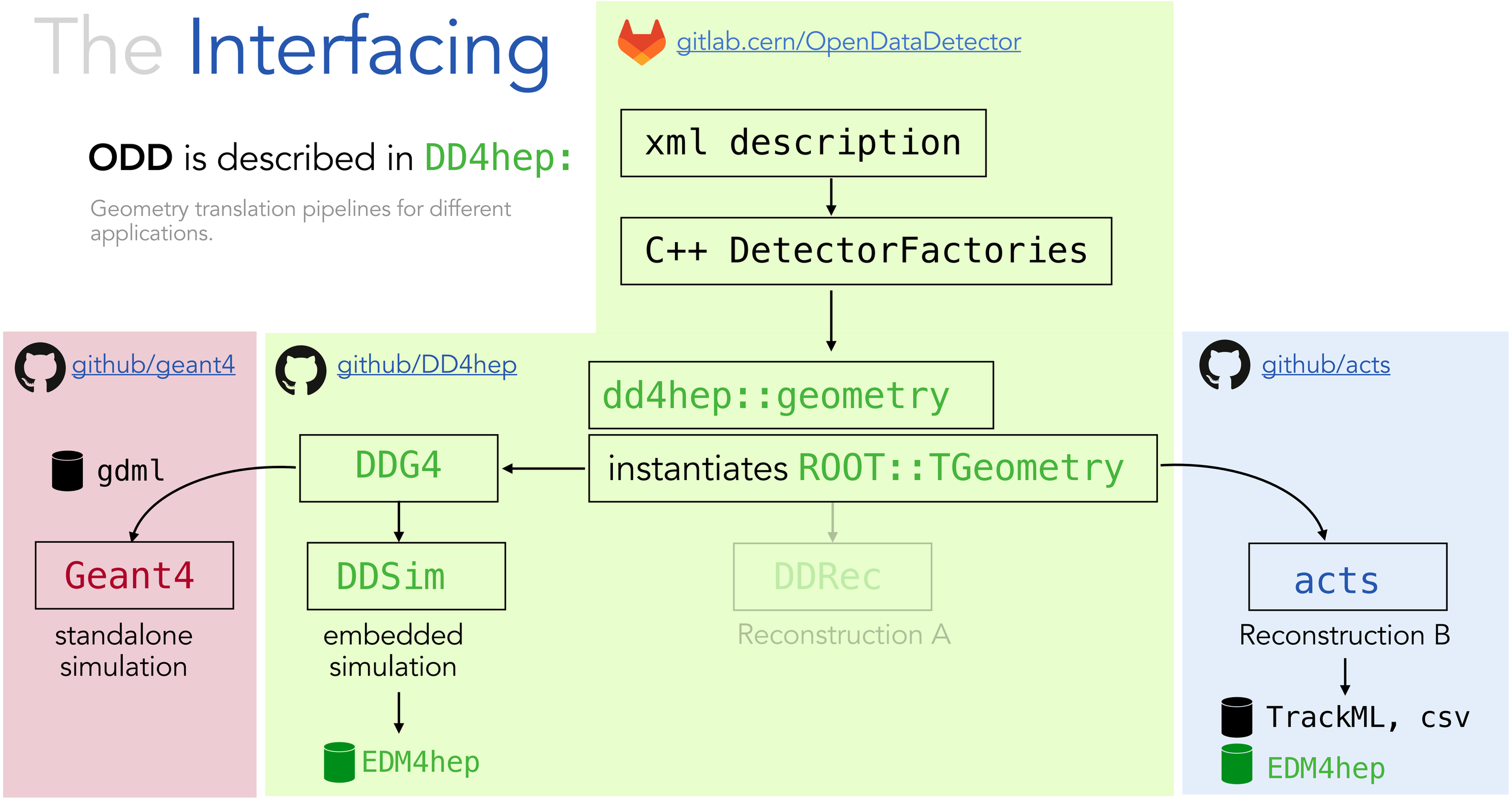
- Silicon based hadronic calorimeter

FCC-hh Tile calorimeter - adjusted in size - to fit around the current ODD Tracker and EM Calorimeter [not in repository yet] .

The Interfacing

ODD is described in DD4hep:

Geometry translation pipelines for different applications.

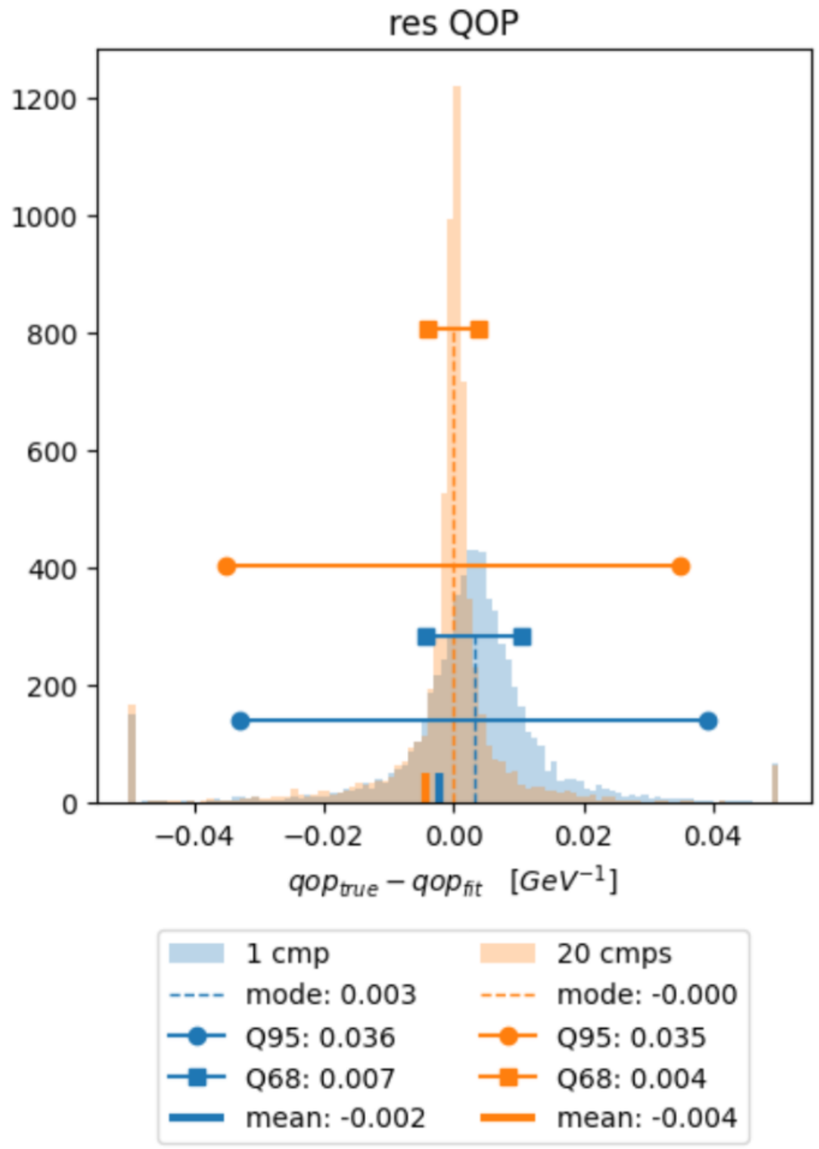


The Usage

The **ODD** Tracking detector is heavily in use In the development of the ACTS track reconstruction toolkit.

- development and testing of algorithms in a realistic environment
- basis of the performance and regression monitoring of ACTS

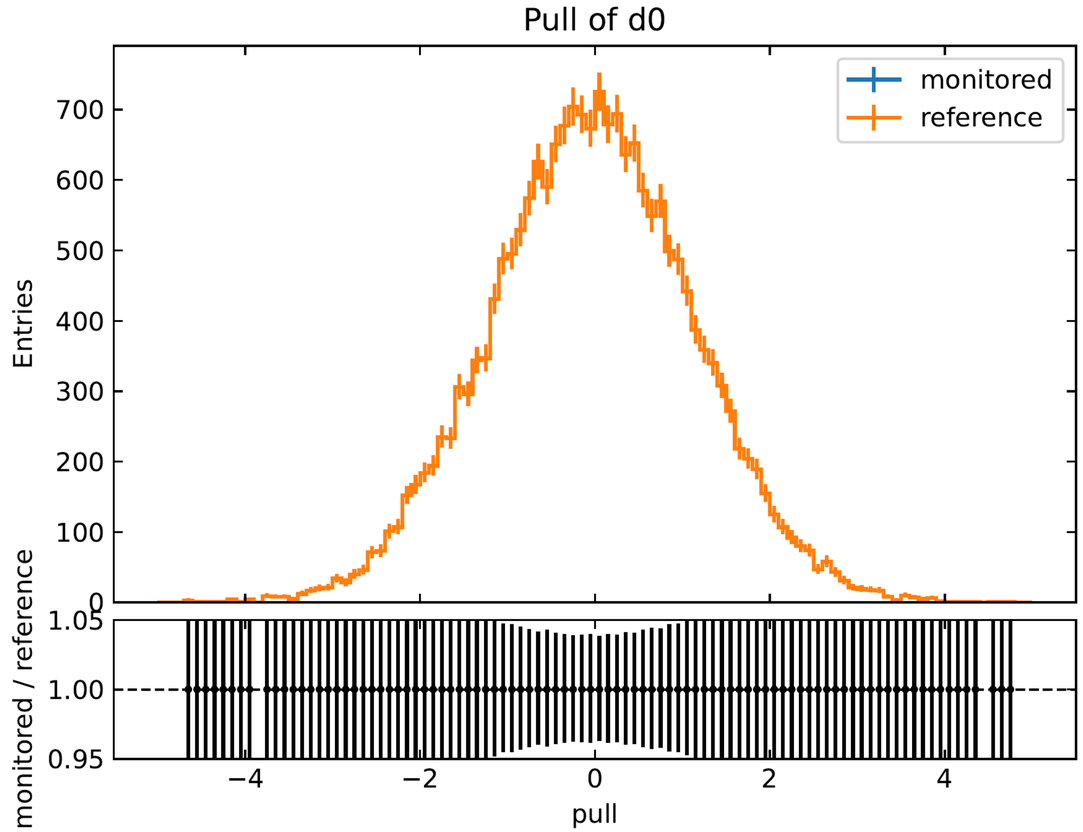
A realistic detector is essential to allow for State-of-the art R&D and testing.



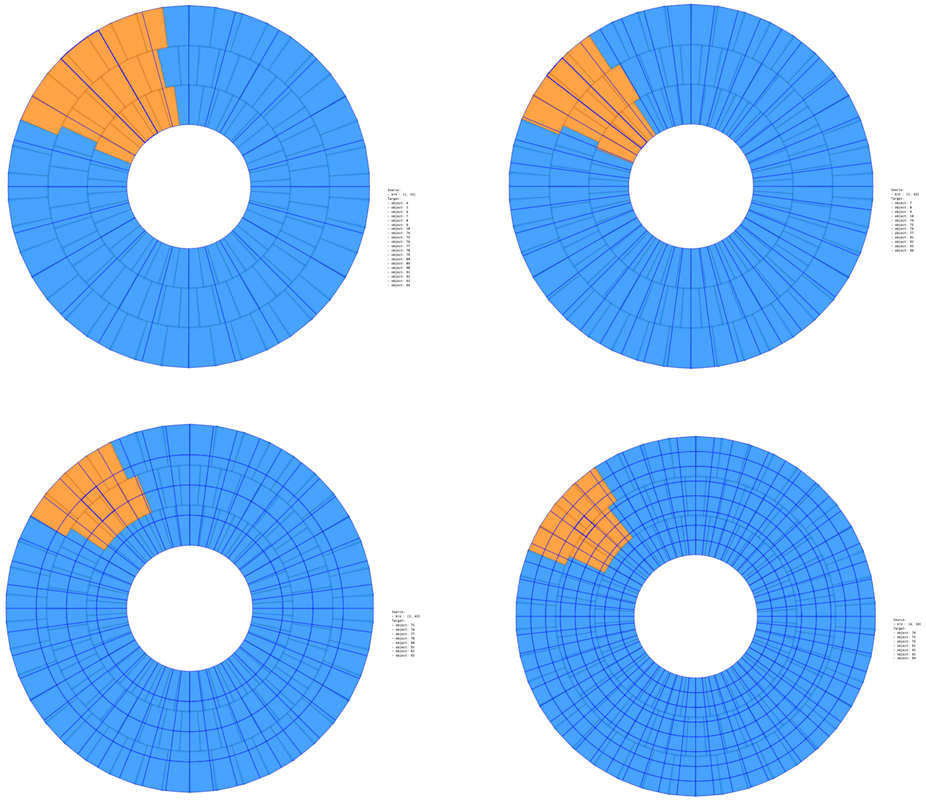
Example: development of GSF track fitter

The Usage

The **ODD** detector provides a traceable platform for performance monitoring, algorithm development and optimisation.



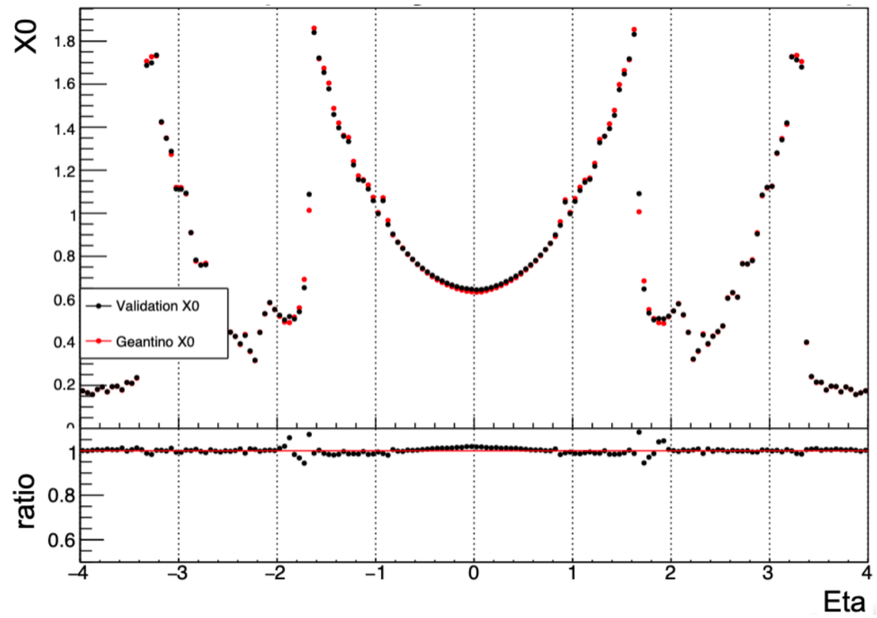
Example: physics performance monitoring in ACTS.



Example: Surface binning optimisation in ACTS for an ODD SS end cap.

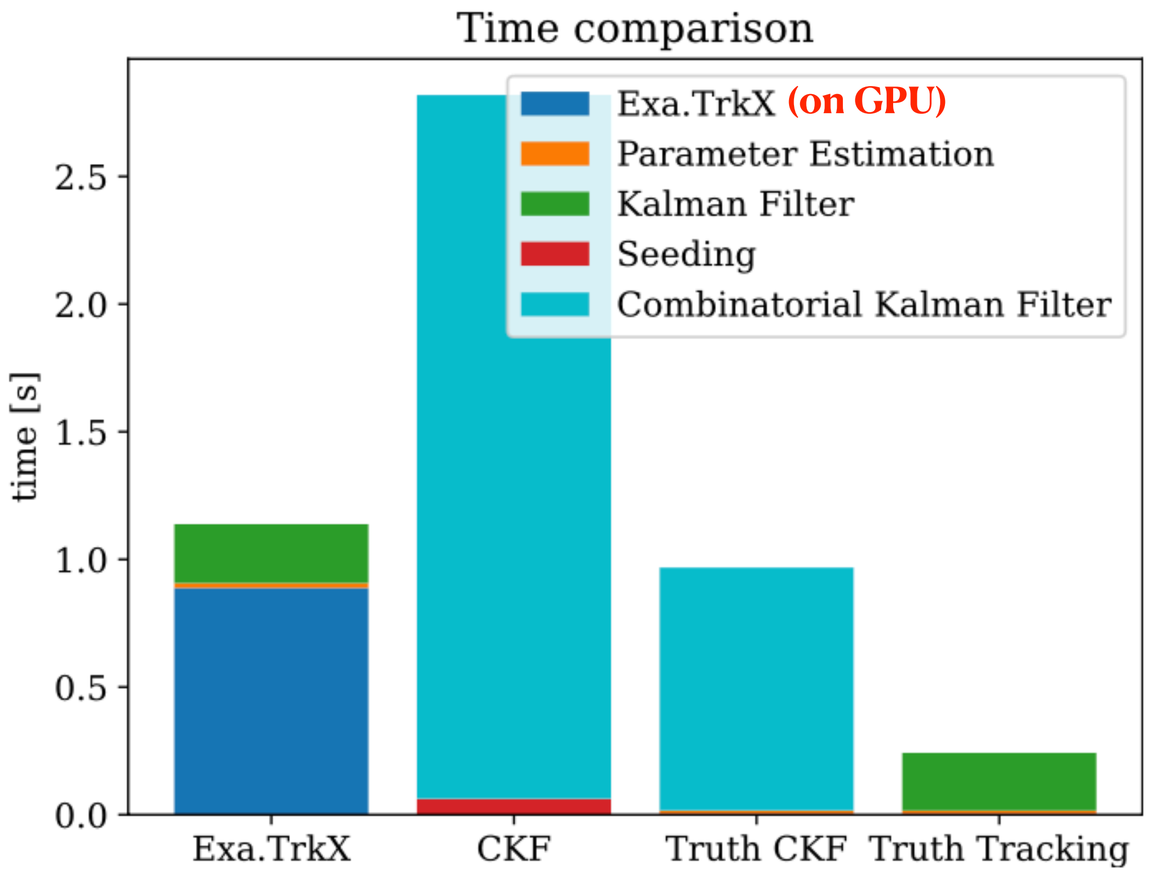
The Usage

The **ODD** detector provides a unique test bed for comparing machine learning based models with numerical/ classical algorithms.



Example: auto-tuning of material map binning in ACTS reconstruction geometry, comparison to Geant4 material budget.

[more @ CHEP23: ML ambiguity solving]



Example: Comparison of execution speed of Exa.TrkX pipeline with various combinatorial pattern recognition derivates.

[more @ CHEP23: Exa.TrkX results]

The Potential

ODD is planned to yield the a large dataset as a replacement of the **TrackML** dataset.

Expressed interest as a testbed for further Exa.TrkX studies, fast calorimeter simulation (successor of ML Fast Shower Sim Challenge), Geant4 GPU transport development

```
Install dependencies: ROOT, DD4Hep, Geant4, BOOST
```

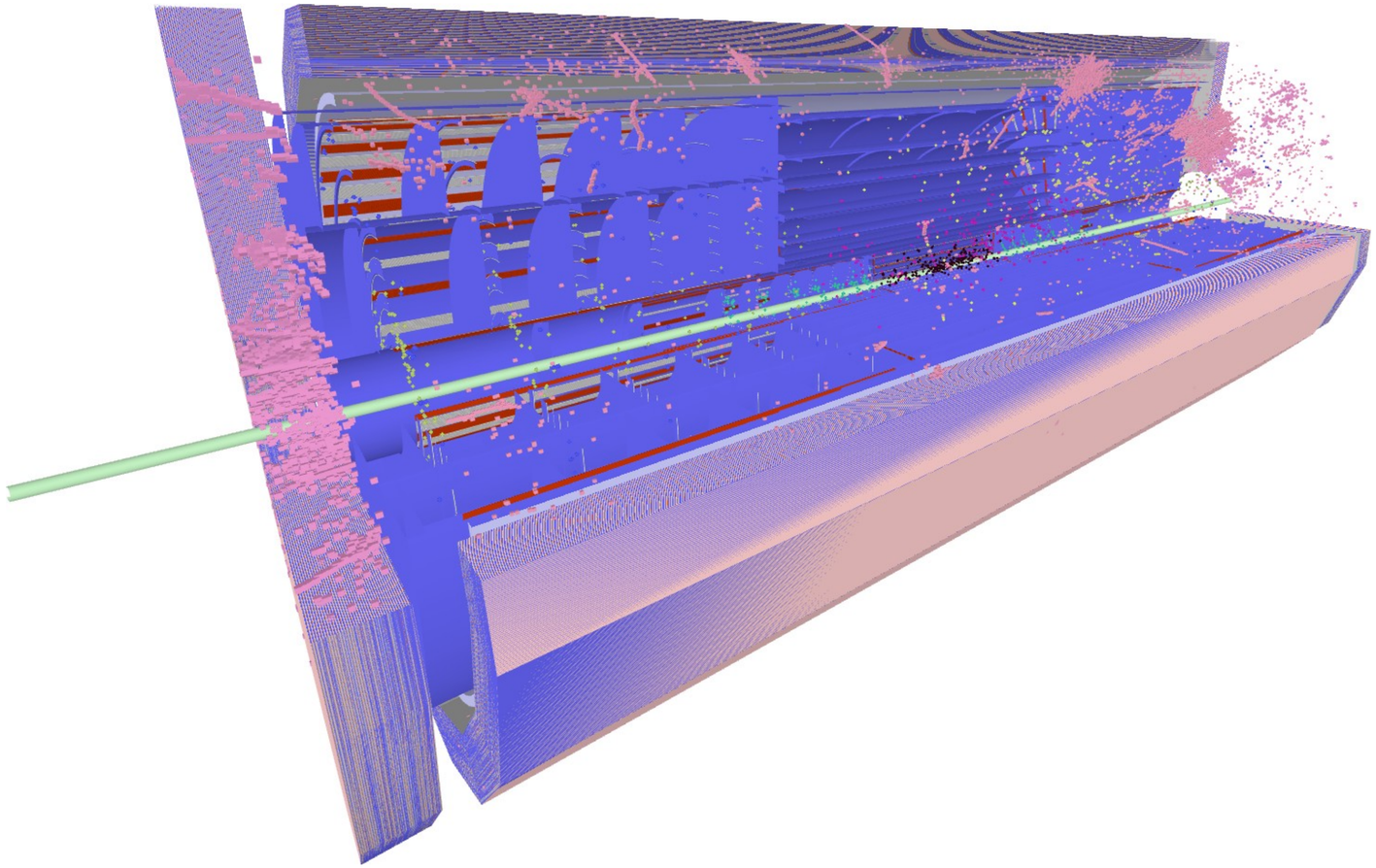
```
git clone https://gitlab.cern.ch/acts/OpenDataDetector.git odd
cmake -S odd -B <b_dir> -DCMAKE_PREFIX_PATH <externals>
cmake --build <path_to_build_area>
```

```
runRDProject(config) | publish([](const auto& rio));
```

MPL2

[more @ CHEP23: ML Calo Challenge]

The Display



Geometry export of **ODD** into ROOT geometry or **.gltf** is part of the continuous integration testing.

gltf file format is directly supported by `phoenix` event display, as is `EDM4hep`.

Alternative display export via ACTS into native **.obj** or **.svg** (via ActSVG).

github/phoenix

PHOENIX

Experiment Independent Event Display

Geant4 simulation of ttbar event displayed with Phoenix

The Summary

With the **ODD** we try to establish the next generation detector model for algorithmic and computing R&D

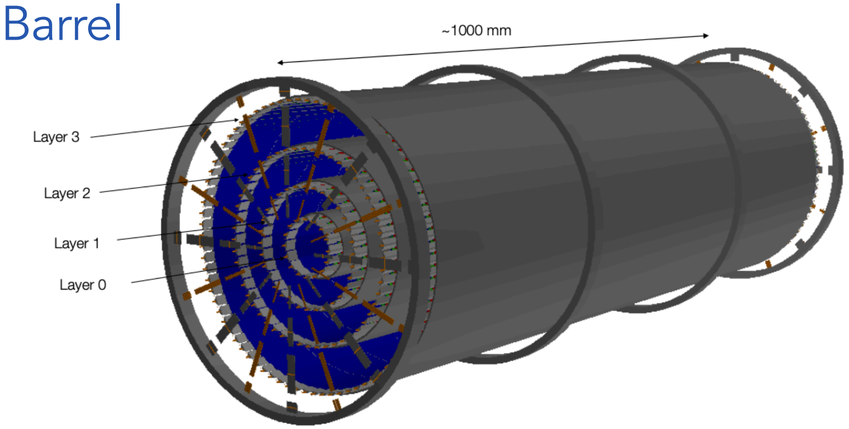
- Highly realistic detector description and material modelling
  Tracking detector and EM calorimeter defined and optimised
- Supporting both fast (ActsFatras) and full simulation (Geant4)
- Embedded in DD4hep/EDM4hep ecosystem
- Extendable, interchangeable

gitlab.cern/OpenDataDetector

mattermost/OpenDataDetector

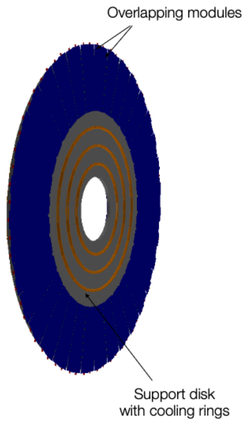
The Details - Pixel System

Barrel



	Radius	Staves phi	Title angle
Layer 0	34 mm	16	0.14
Layer 1	70 mm	32	0.14
Layer 2	116 mm	52	0.14
Layer 3	172 mm	78	0.14

Endcap discs



	Z
Disc N0/P0	∓620 mm
Disc N1/P1	∓720 mm
Disc N2/P2	∓840 mm
Disc N3/P3	∓980 mm
Disc N4/P4	∓1120 mm
Disc N5/P5	∓1320 mm
Disc N6/P6	∓1520 mm

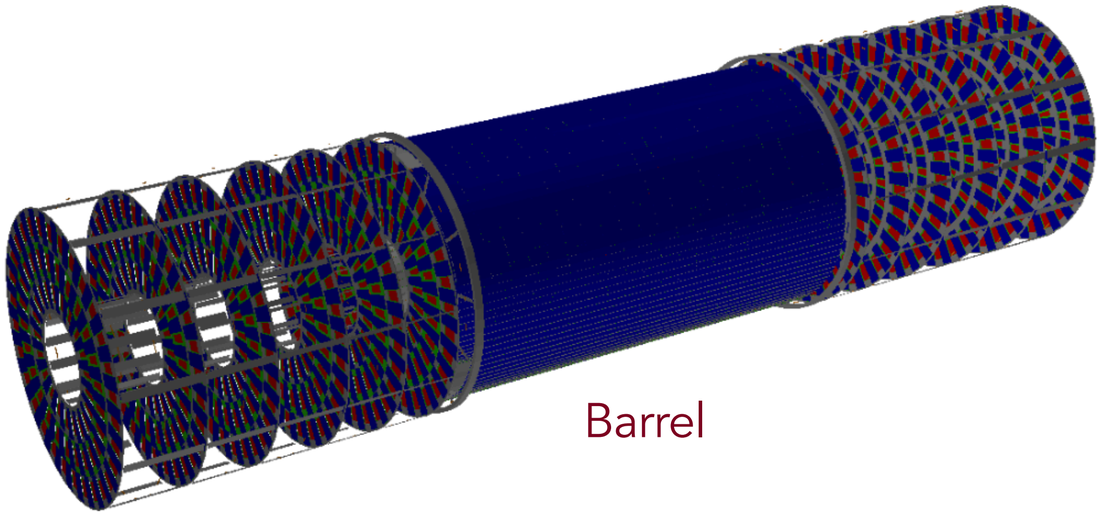
Module Characteristics

Silicon Pixel module

- Barrel (rectangular): 8.4 mm x 36 mm (half lengths)
- Endcap (trapezoidal): 8.5/14.5 mm x 34 mm (half lengths)
  10.5/16.5 mm x 34 mm (half lengths)
- thickness: 125 μm

Configurable pixel size, default 50 μm x 50 μm

The Details - Short Strip System



Barrel

	Radius	Staves phi	Modules z
Layer 0	260 mm	40	21
Layer 1	360 mm	56	21
Layer 2	500 mm	78	21
Layer 3	660 mm	102	21

Endcap

	Z	Rings
Disc N0/P0	∓1300 mm	3
Disc N1/P1	∓1500 mm	3
Disc N2/P2	∓1850 mm	3
Disc N3/P3	∓2200 mm	3
Disc N4/P4	∓2550 mm	3
Disc N5/P5	∓2950 mm	3

Module Characteristics

Single-sided Silicon Strip module

- Barrel (rectangular): 24 mm x 54 mm (half lengths)
- Endcap (trapezoidal): 18.4/32.2 mm x 72 mm (half lengths)
  30.2/44.0 mm x 72 mm (half lengths)
  40.8/36.4 mm x 72 mm (half lengths)
- thickness: 250 μm

Configurable pitch size, default 50 μm

The Details - Long Strip System

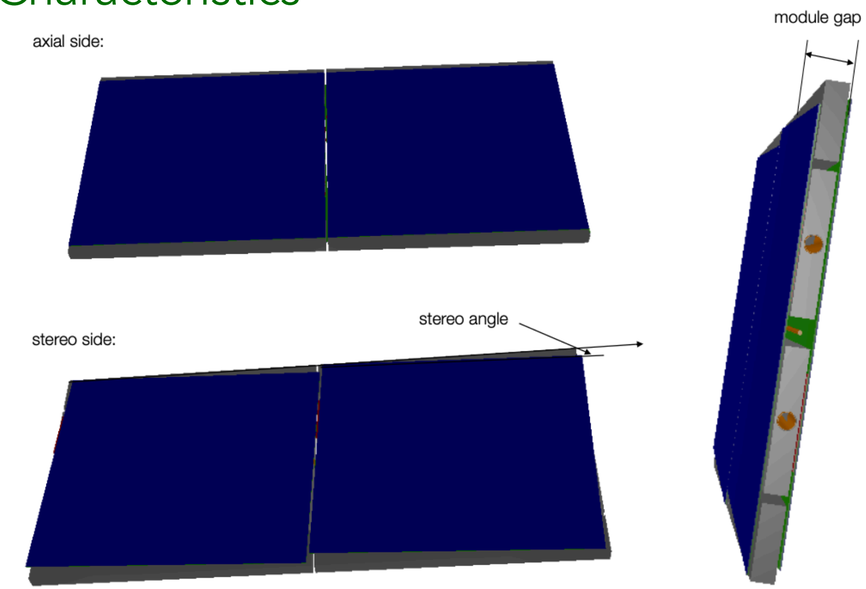
Barrel

	Radius	Staves phi	Modules z
Layer 0	260 mm	40	21
Layer 1	360 mm	56	21

Endcap

	Z	Rings
Disc N0/P0	∓1300 mm	2
Disc N1/P1	∓1600 mm	2
Disc N2/P2	∓1900 mm	2
Disc N3/P3	∓2250 mm	2
Disc N4/P4	∓2600 mm	2
Disc N5/P5	∓3000 mm	2

Module Characteristics



Double-sided Silicon Strip module
- Barrel (rectangular): 96 mm x 108 mm (half lengths)
- Endcap (trapezoidal): 53.2/58.6 mm x 78 mm (half lengths)
  64.6/70 mm x 78 mm (half lengths)

- thickness: 250 μm
- stereo angle: 0.04

Configurable pitch size

The Details - EM calorimeter

Barrel

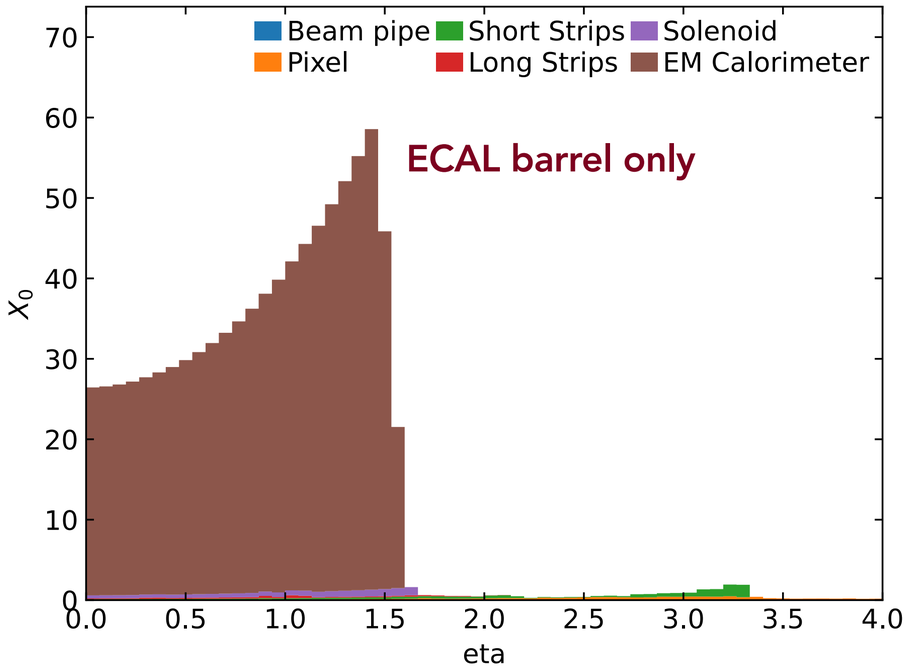
Hexadecagon (16-side polygon), 48 layers

Inner R	1250 mm
Outer R	1500 mm
Halflength Z	3050 mm

Endcap

40 layers

Inner R	340 mm
Outer R	1500 mm
Range Z	∓ [3200-3450] mm



Characteristics

ECAL with high granularity
- CALICE type, proposed for CLIC, CLD and ILD
- inspired CMS HGCal

Active pads:
- Silicon 5.1 mm x 5.1 mm Silicon
- Absorber: Tungsten