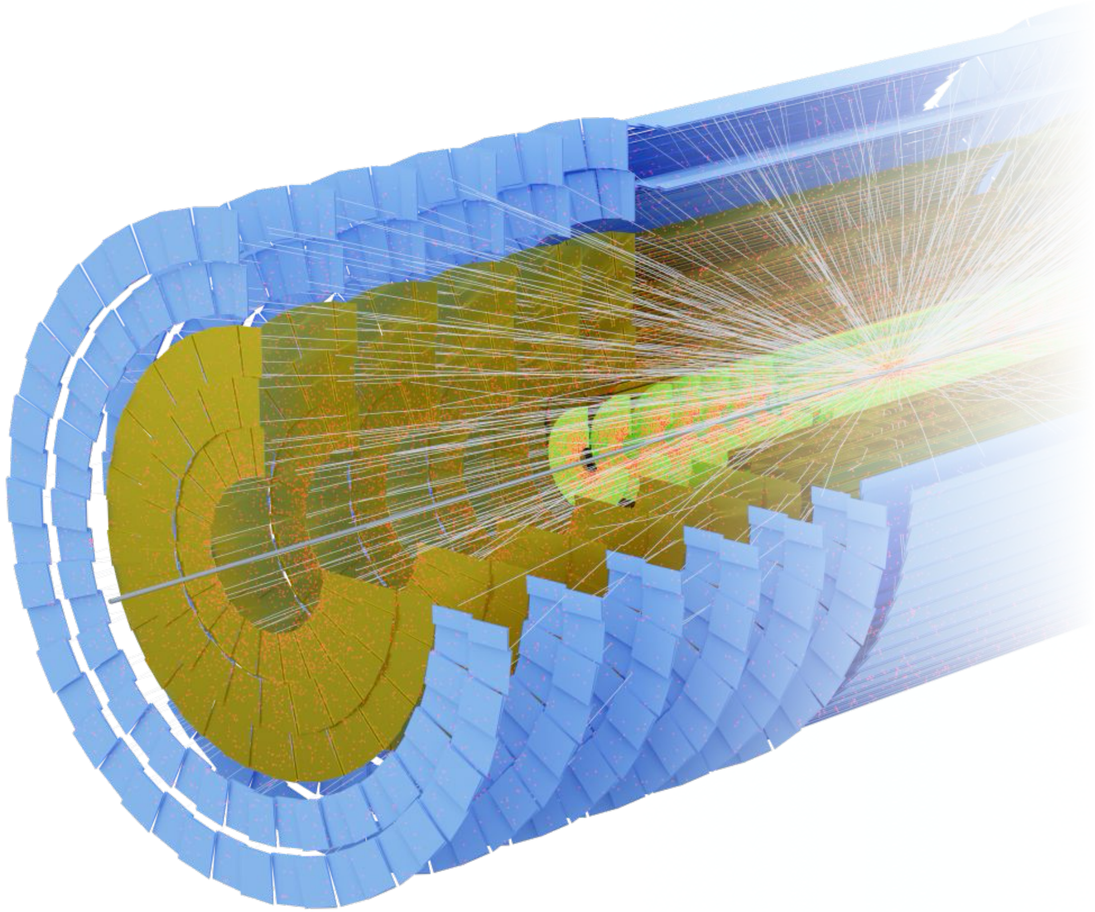
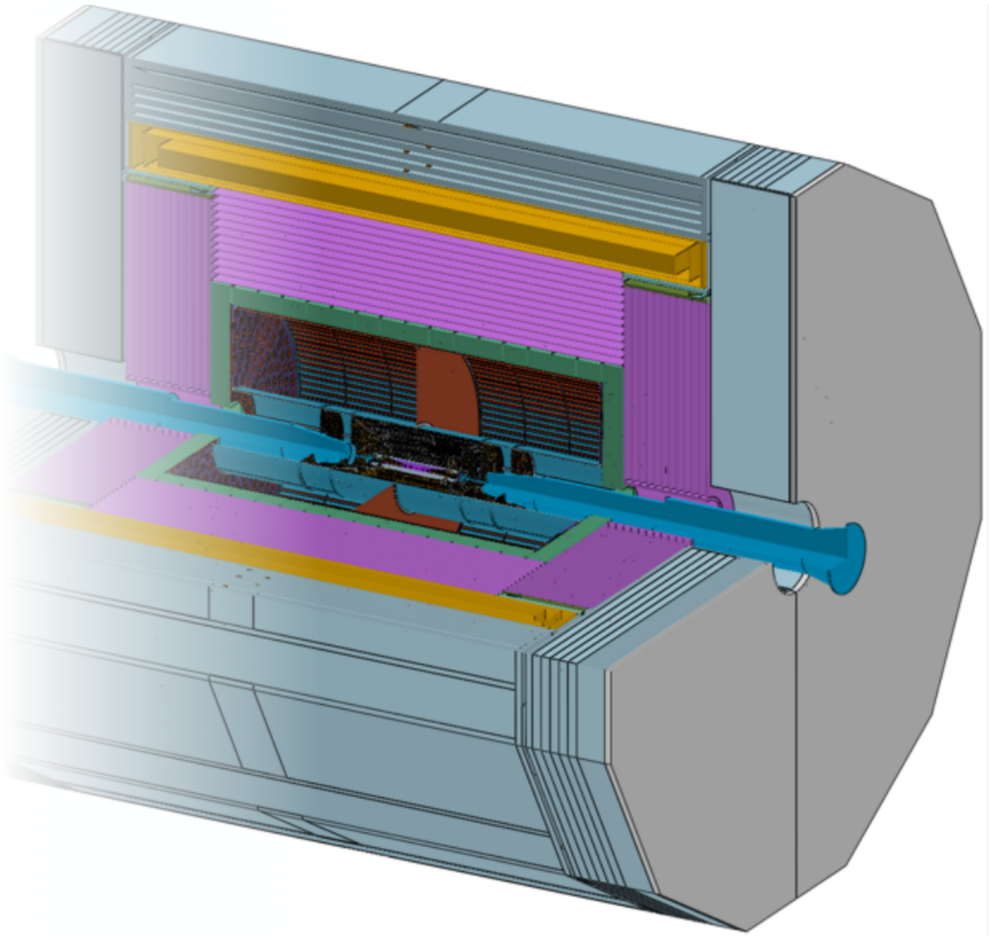




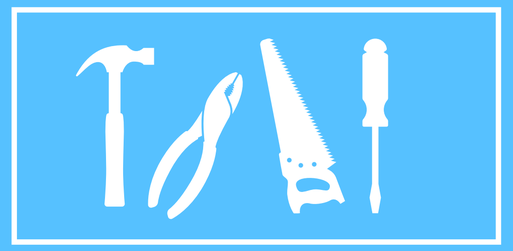
The a(ts) software

… and its application to CEPC

A. Salzburger (CERN)

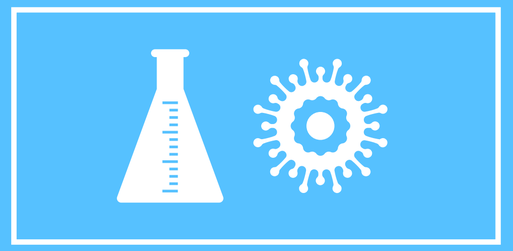
X. Ai (Zhengzhou University)
W. Li, T. Ling, Y. Zhang (IHEP)

Mission statement



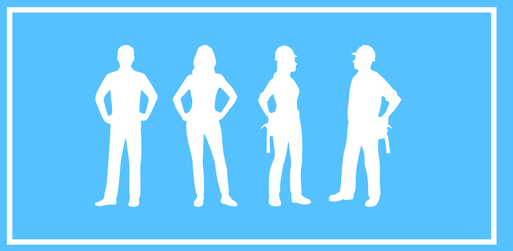
TOOLBOX

for experiments to assemble high quality track reconstruction



R&D PLATFORM

for algorithmic and technology research



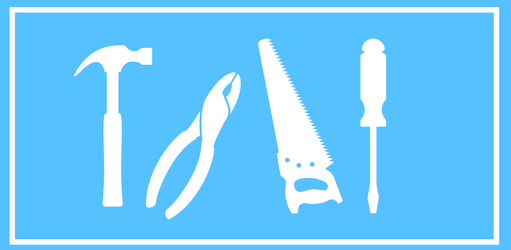
COMMUNITY

to foster inter-experiment exchange and development

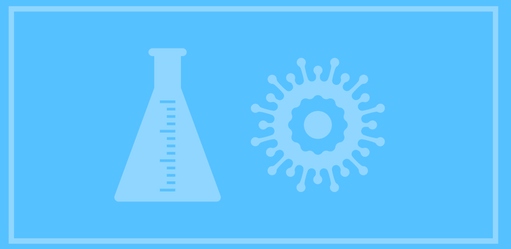
An [extended version] of this talk can be found as the introduction of the ACTS4NP Workshop, May 20225, Berkeley, US

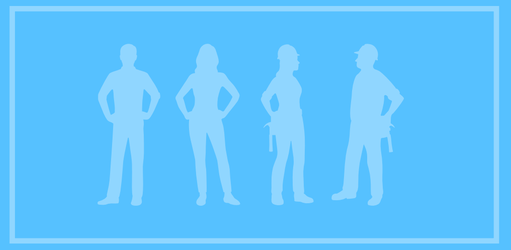
Many possibilities to contribute and enhance the project

Built upon a huge stack of experience and knowledge

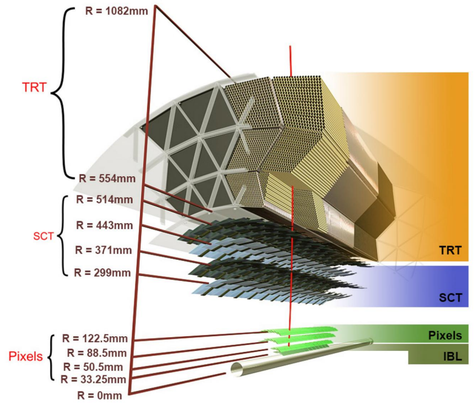


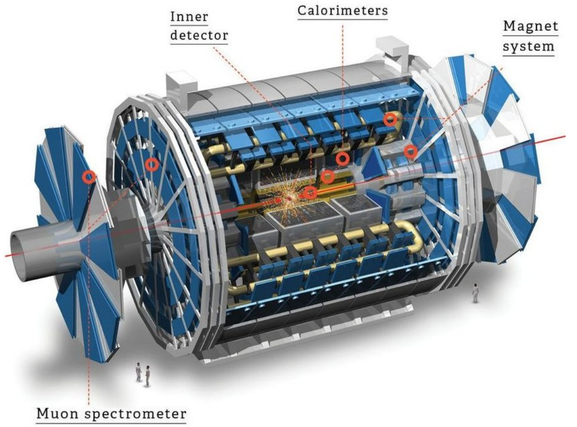
TOOLBOX





Common track reconstruction code for ATLAS
Inner Detector and *Muon Spectrometer*

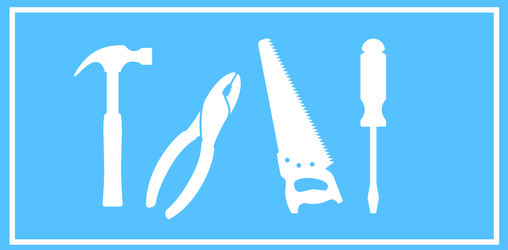




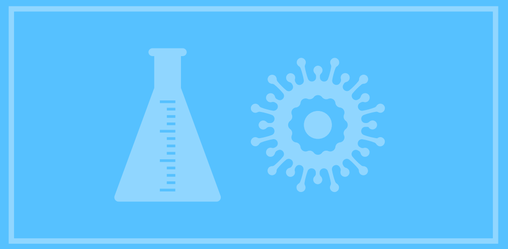
2 very different tracking systems with different technologies:
ATLAS was forced to develop some common/generic code

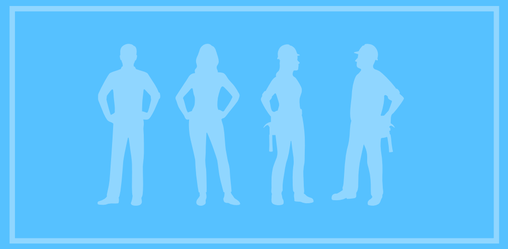
Generalised ATLAS Tracking code an imported into a standalone repository that became A(C)TS (initial commit Nov 11, 2015)

A lot of the concepts are based on ATLAS Run 1-2-3 tracking code, however, significant extensions/augmentations are have happened ever since.



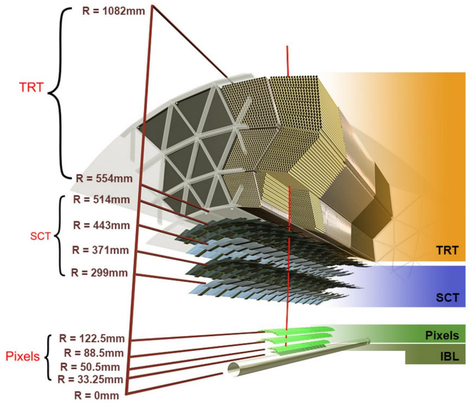
TOOLBOX

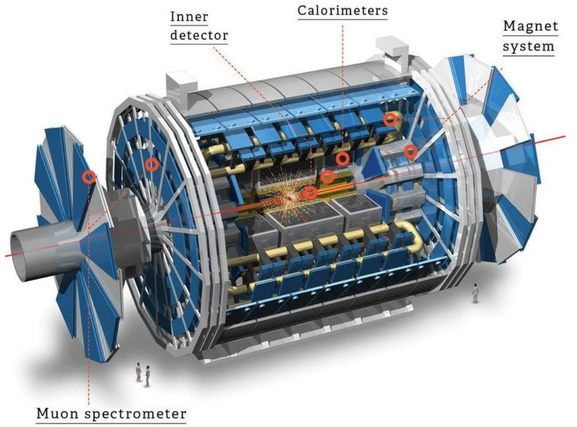




Common track reconstruction code for ATLAS

Inner Detector and *Muon Spectrometer*



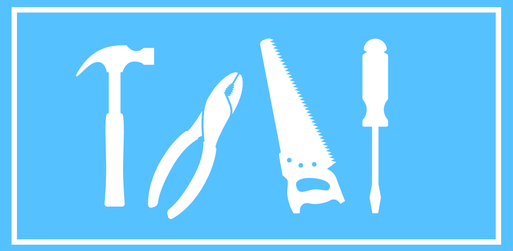


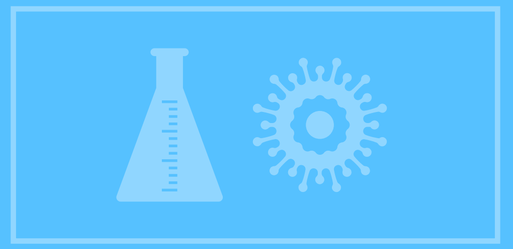
2 very different tracking systems with different technologies:

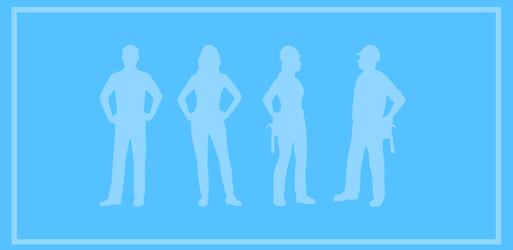
ATLAS was forced to develop some common/generic code

Given the historic origin of the project, several algorithms have an implicit bias towards working better for collider-like experiments,

Wherever possible we are trying to remove this bias w/o losing the underlying features and power.



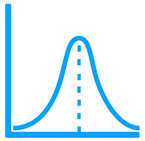




What is in the toolbox?

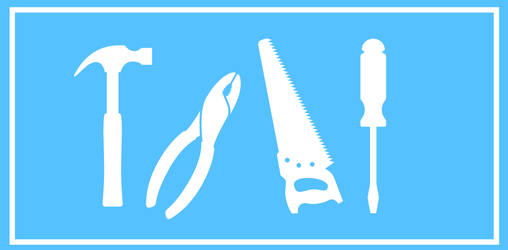
Geometry & Material

Event Data Model

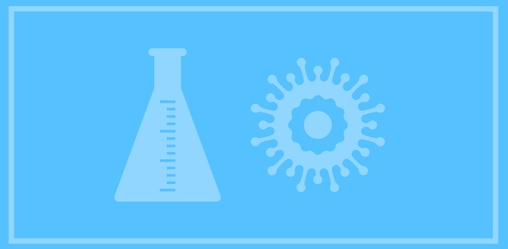


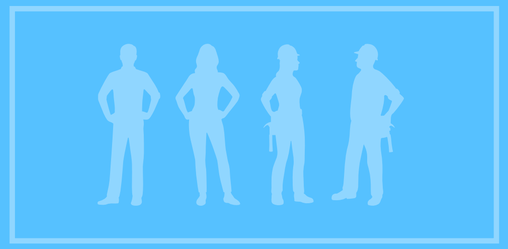
Track Finding & Fitters

Vertexing



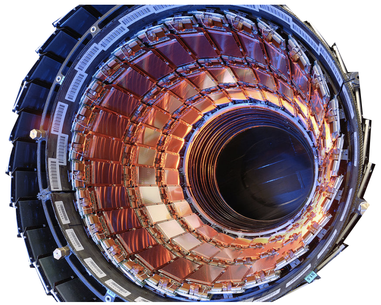
TOOLBOX



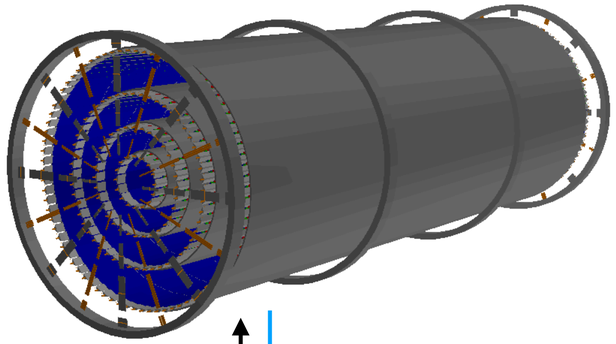


Geometry:

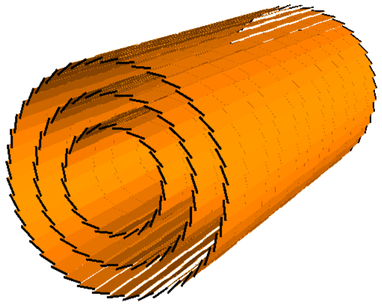
Reality



Full simulation



Reconstruction



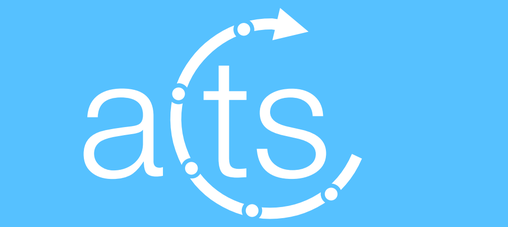
Relatively detailed description
using a 3D geometry modeller
(DD4hep, TGeo, GeoModel)
usually interfaced to Geant4

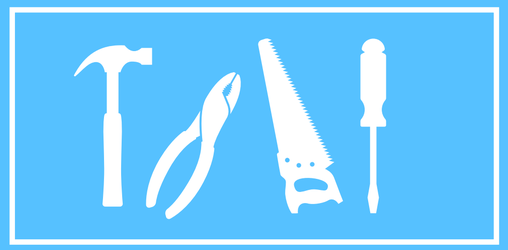
Geometry building in ACTS:

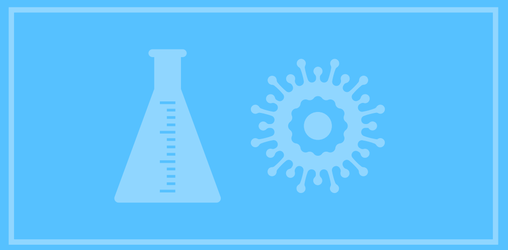
- representing sensitive surfaces
- simplifying material

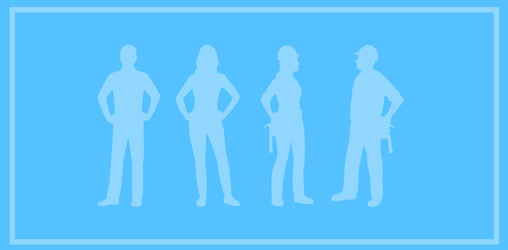
ACTS material mapping mechanism

acts / Core



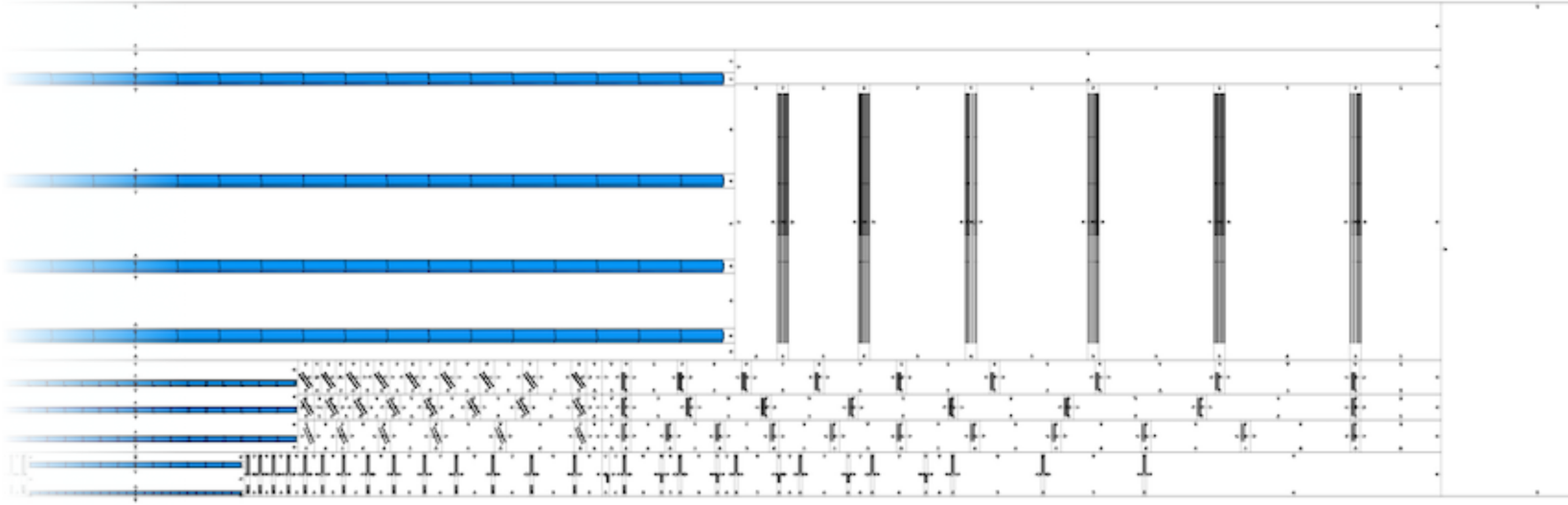






Geometry & Material

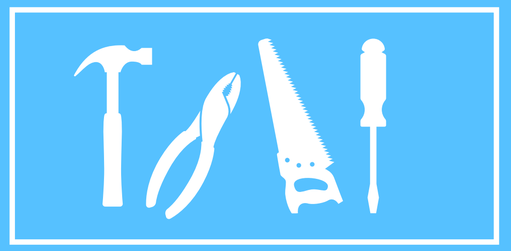
ACTS then translates this into a fully navigable geometry model



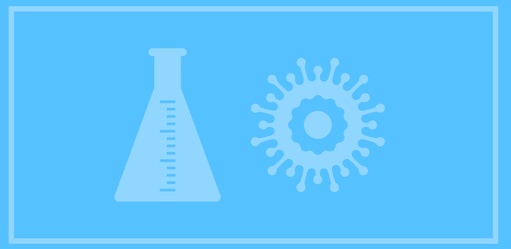
Navigation model of
Open Data Detector (ODD)

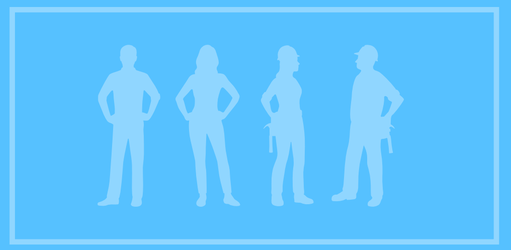
This comes **together with an embedded navigation:**
core of most track finding and fitting modules

acts / Core



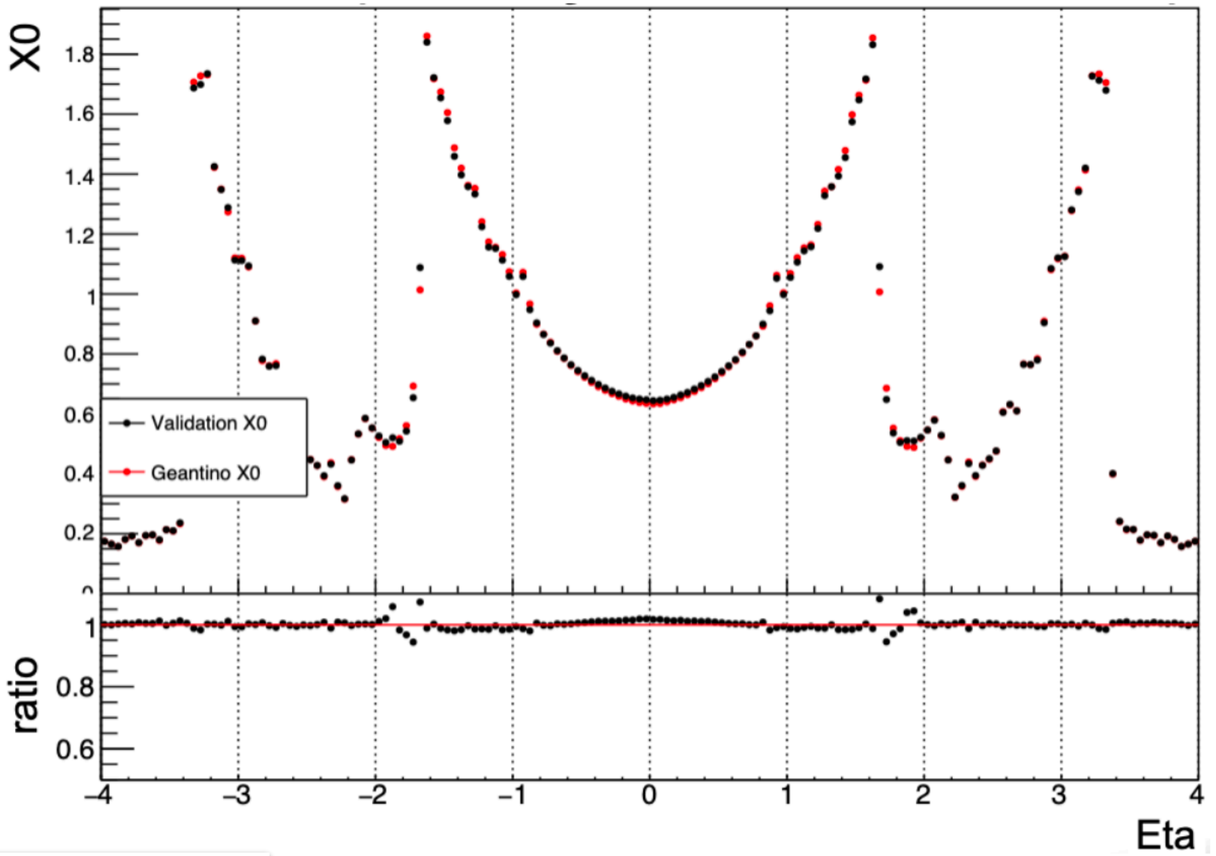
TOOLBOX



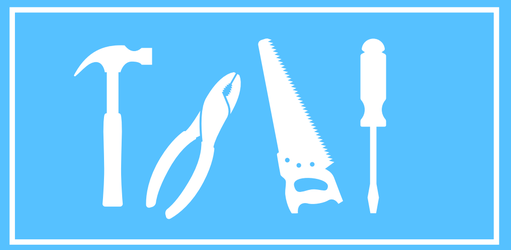


Geometry & Material

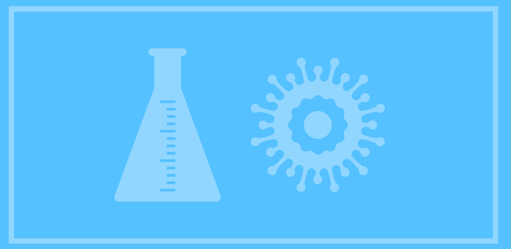
ACTS material mapping allows quasi-exact material modeling

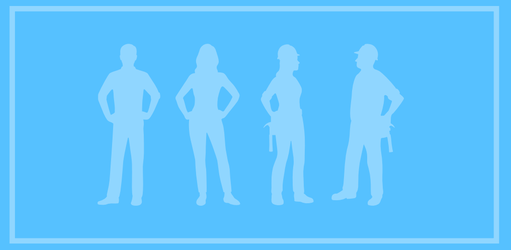


acts / Core



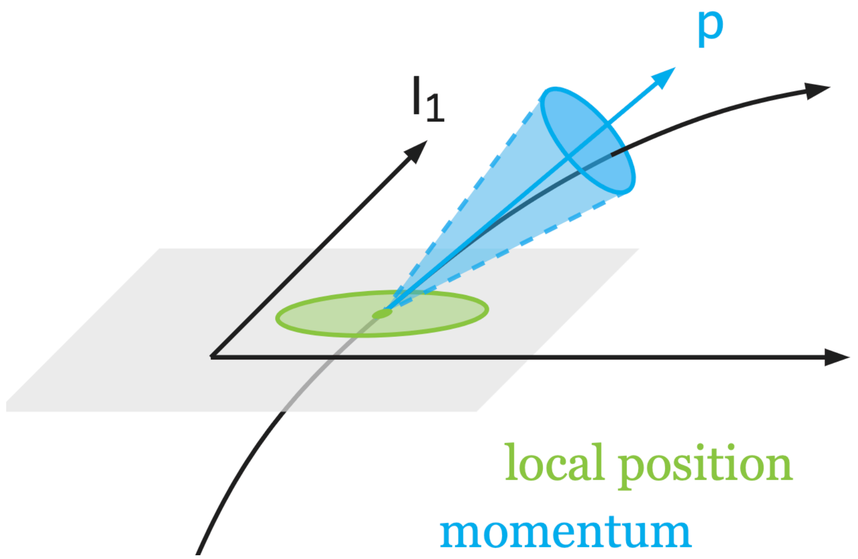
TOOLBOX

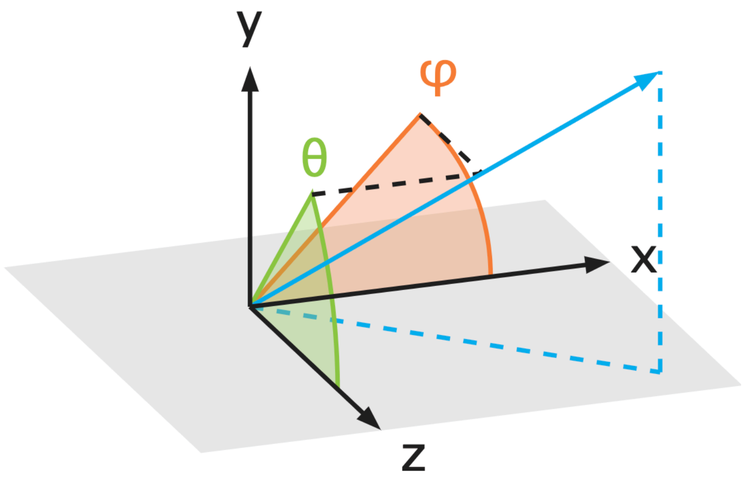




Event Data Model:

e.g. track parameterization

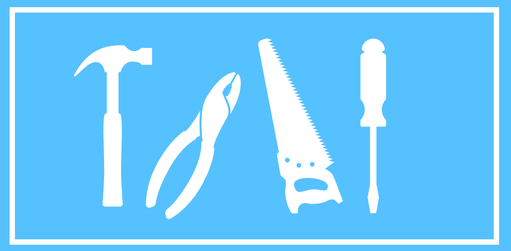




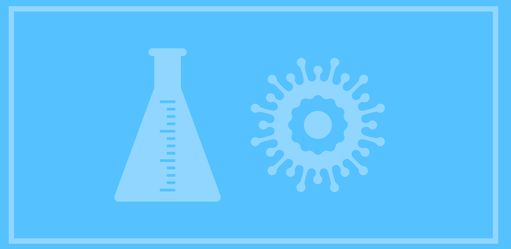
$$\vec{x} = (l_0, l_1, \phi, \theta, q/p, t)^T$$

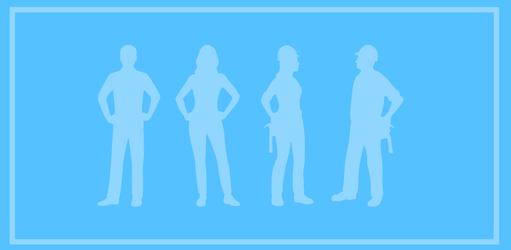
acts / Core

In addition: measurement representation, tracks (multi-trajectory), vertices, …



TOOLBOX





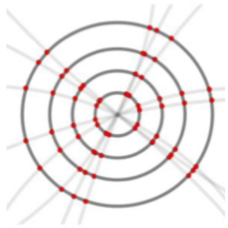
Algorithms:

ACTS deploys a series of algorithms & algorithmic chains:

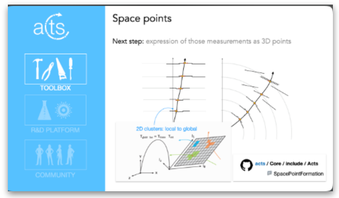
- **First stage pattern recognition:**
  - clustering & space point formation
- **Seeding & track following:**
  - Different seeding algorithms
  - Combinatorial Kalman Filter
- **Global pattern recognition:**
  - Hough transformation
- **Track fitting:**
  - Kalman filter, Gaussian Sum filter, Global Chi2 Fitter
- **Vertex reconstruction:**
  - Iterative finding, Annealing based finding
  - Billoir Fitter, Multi Adaptive Fitter

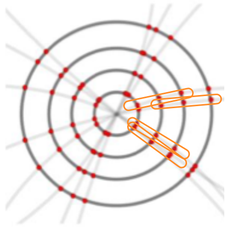
Summary: baseline track reconstruction chain

TOOLBOX

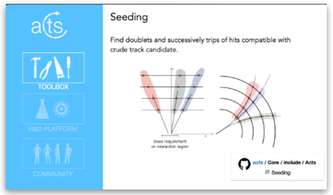


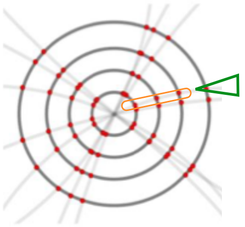
Hits



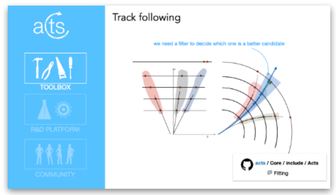


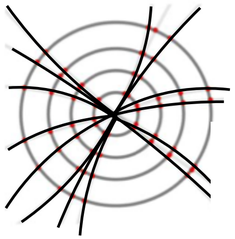
Seeds



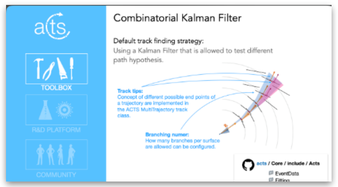


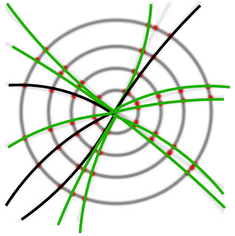
Track Candidates

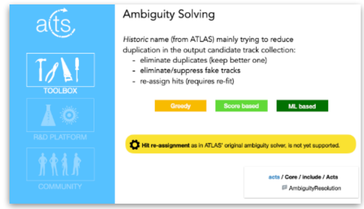




Tracks



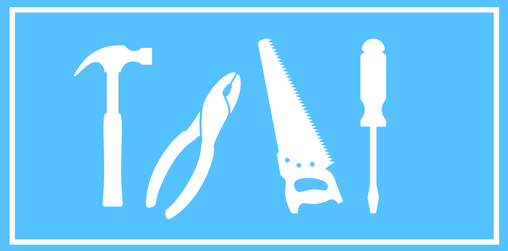




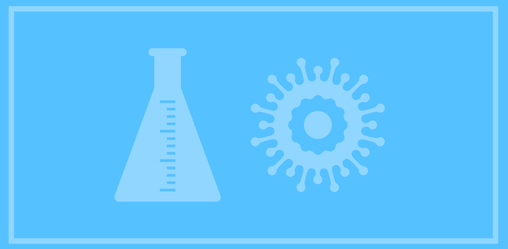
Resolved Tracks

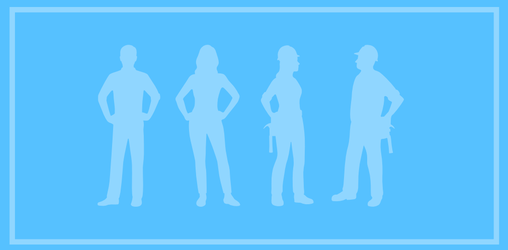
acts / Core

Summary: baseline track reconstruction chain



TOOLBOX





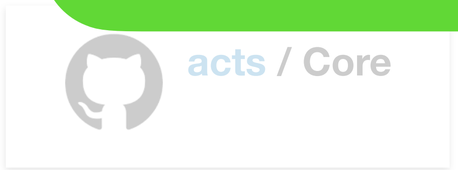
Baseline:

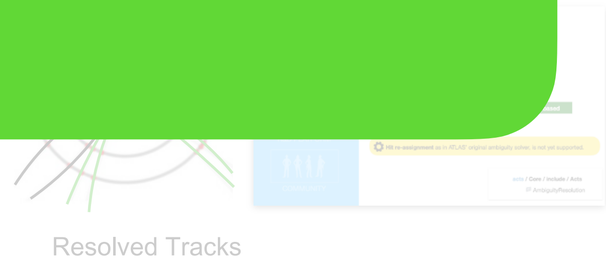
Ready-to use tools, that *only* require embedding into an experiment's software framework & geometry.

CPU targeted, fully **C++20** compliant

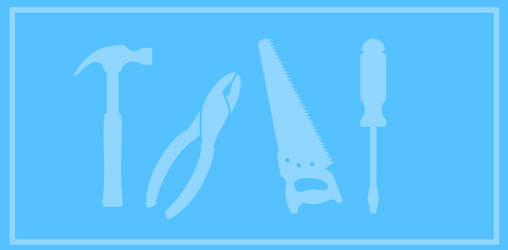
Design-level parallelism and contextual data (conditions data) support:

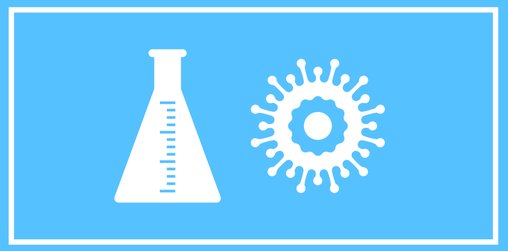
- **alignable detectors**
- **calibration and detector conditions data**



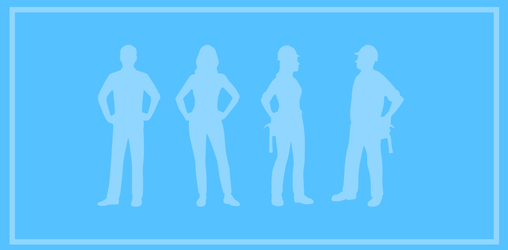


Resolved Tracks

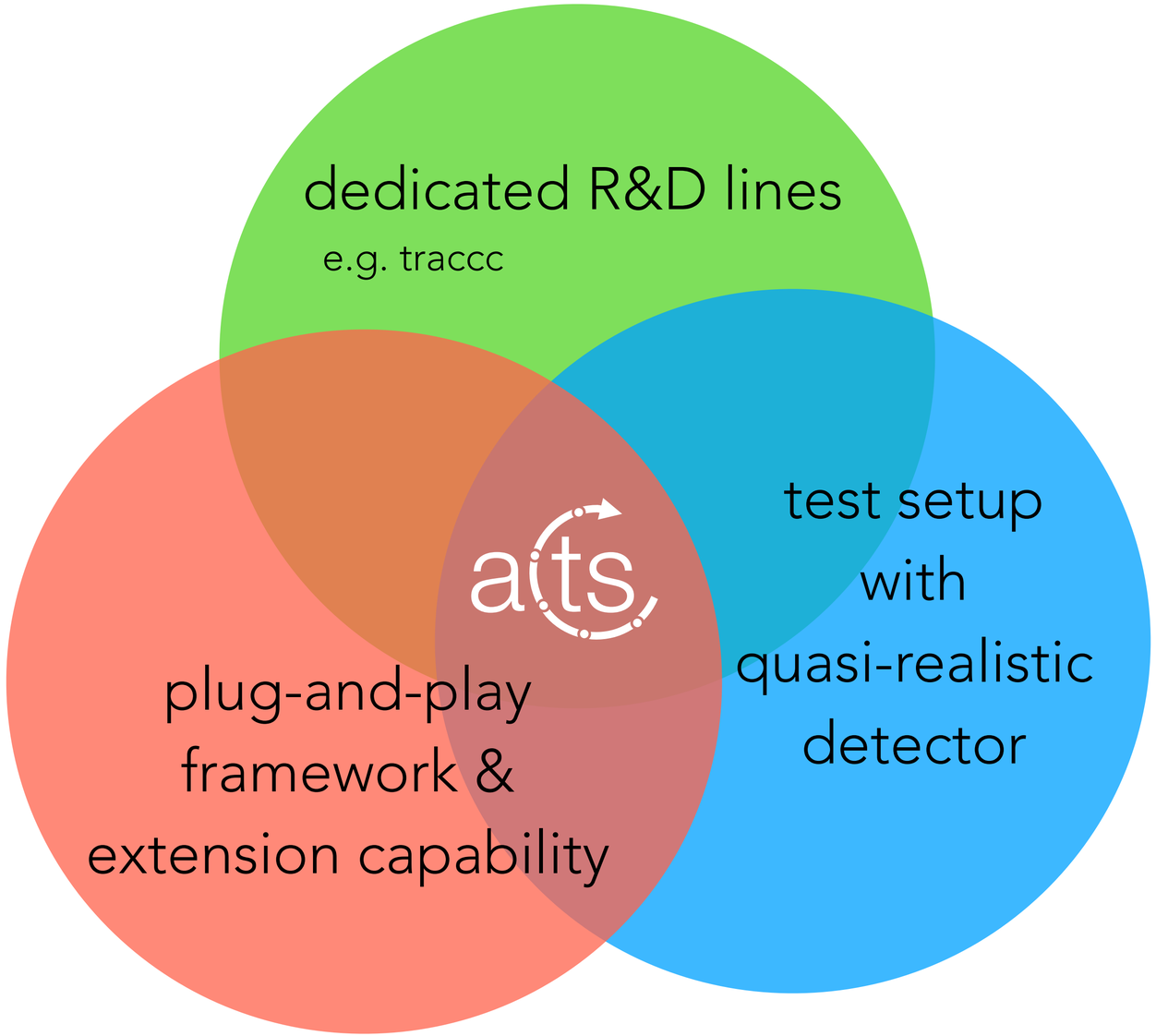


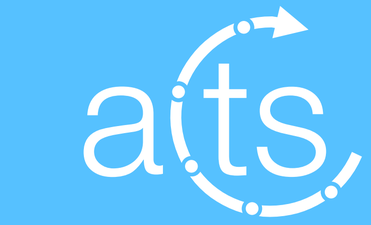


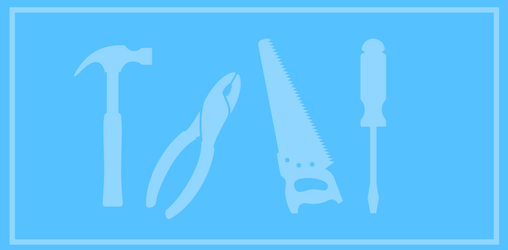
R&D PLATFORM

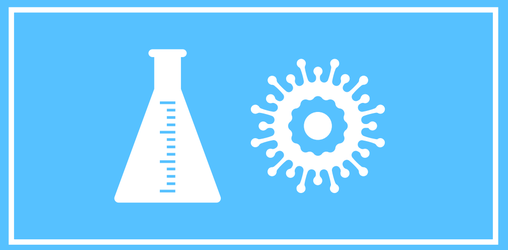


Enabling R&D is a key aspect

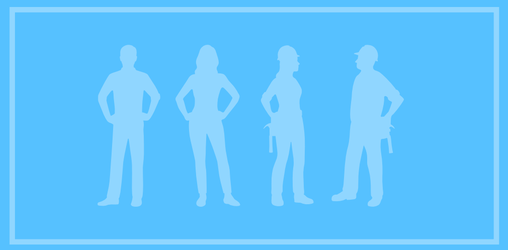








R&D PLATFORM

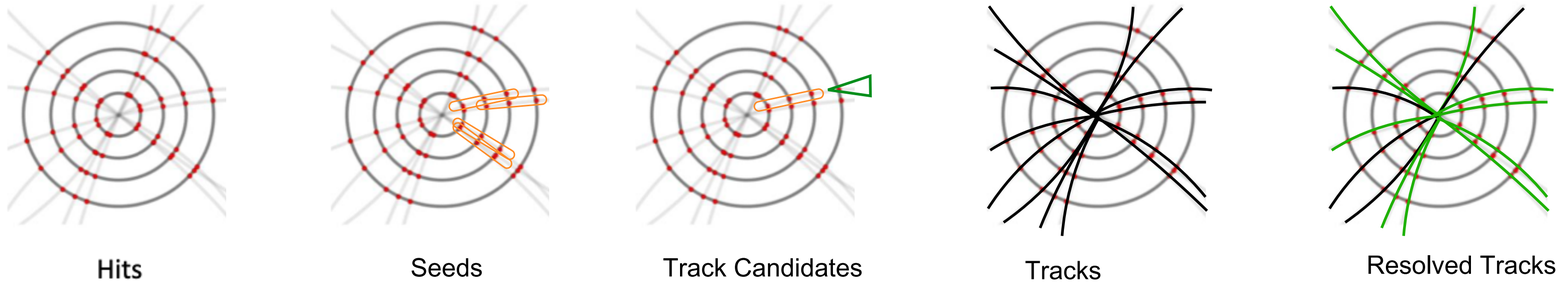


Track reconstruction on GPUs

traccc

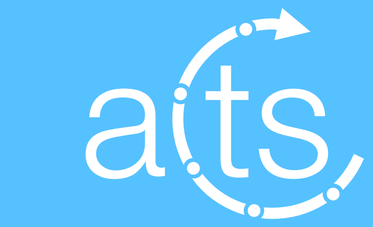
traccc is the umbrella project for our massively parallel track reconstruction aiming an GPGPUs

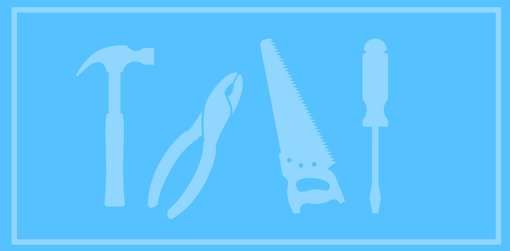
split off into a dedicated set of repositories (currently) to allow and facilitate disruptive development

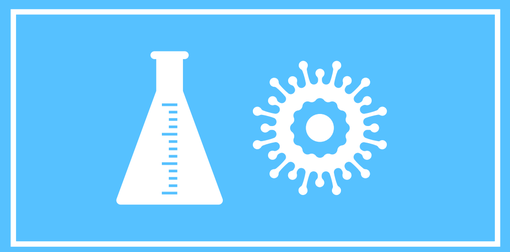


Re-implementation of this chain, including all aspects mentioned.

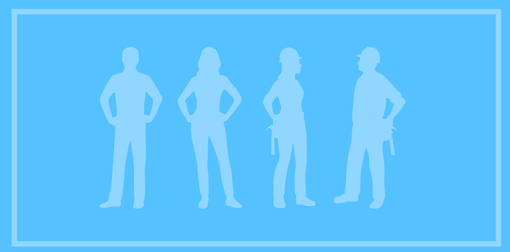
Aim is to provide **offline-quality reconstruction** on GPUs.

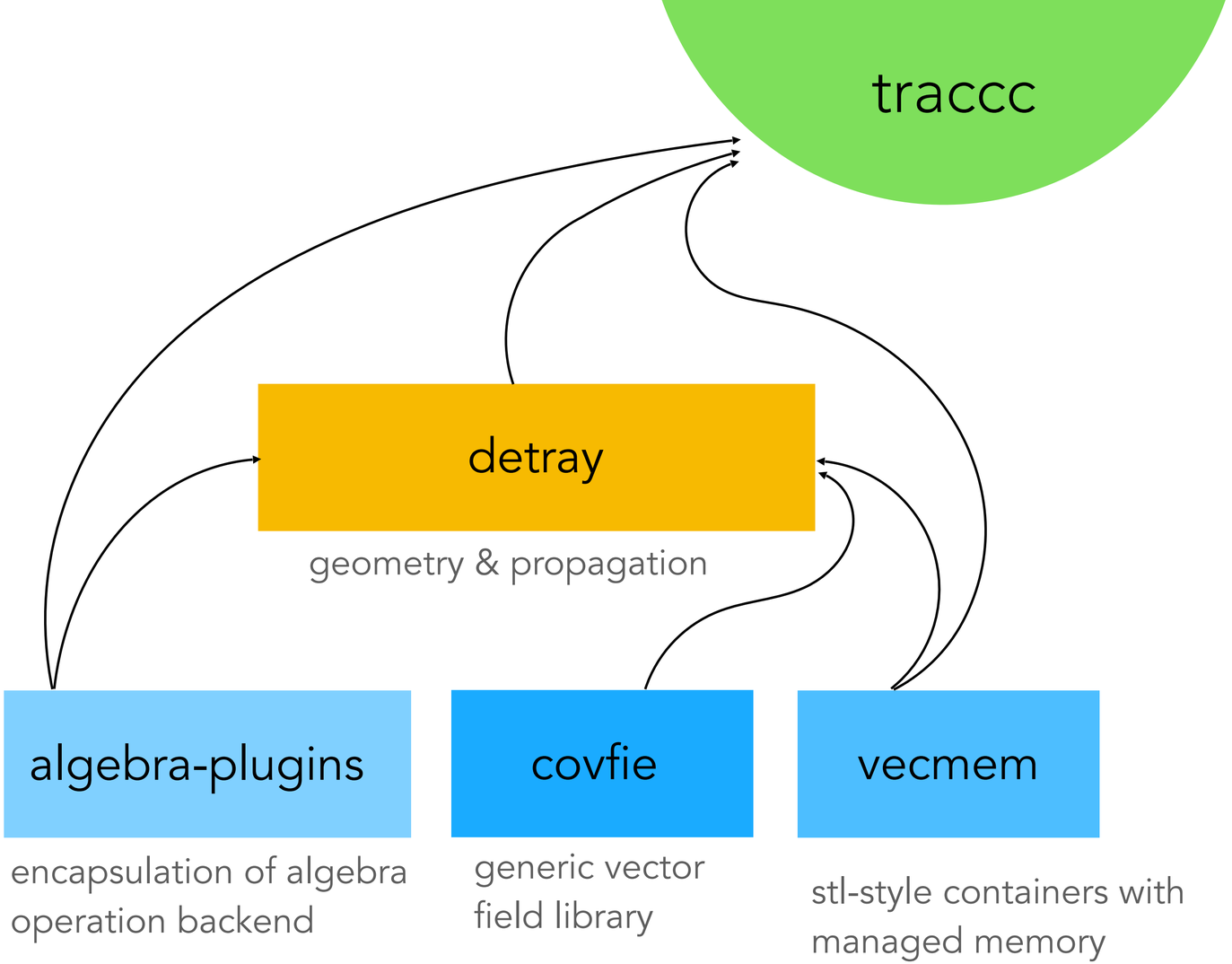


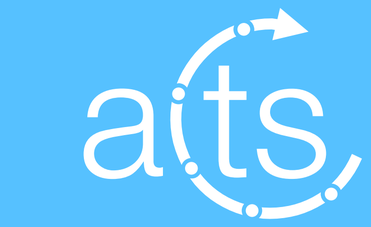


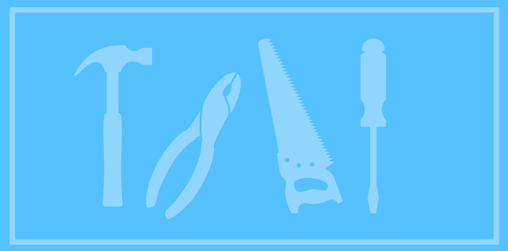


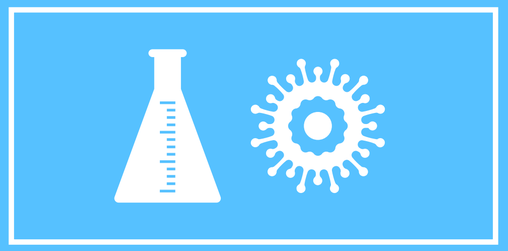
R&D PLATFORM



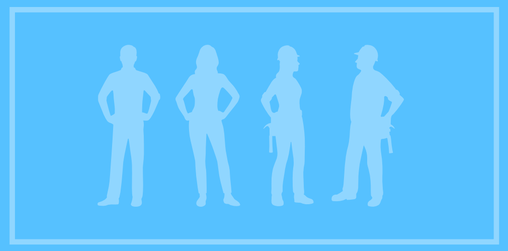

traccc
detray
geometry & propagation
algebra-plugins
covfie
vecmem
encapsulation of algebra operation backend
generic vector field library
stl-style containers with managed memory







R&D PLATFORM

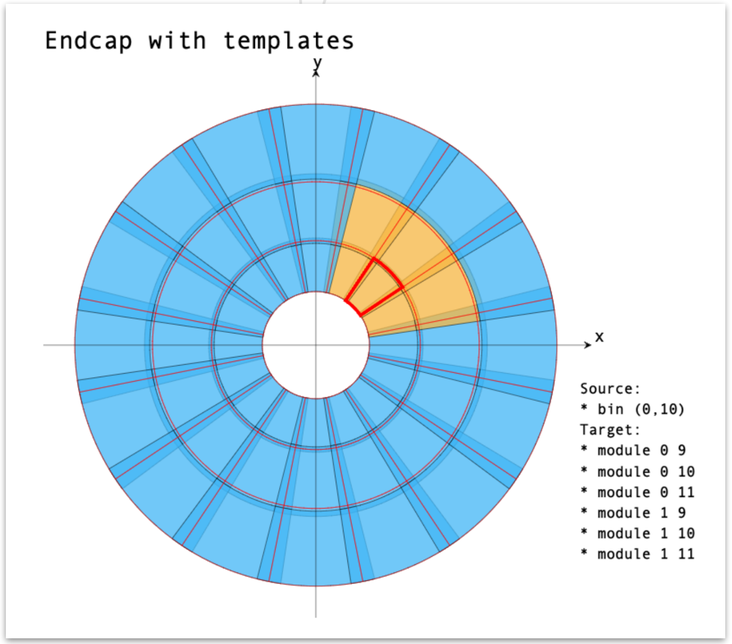


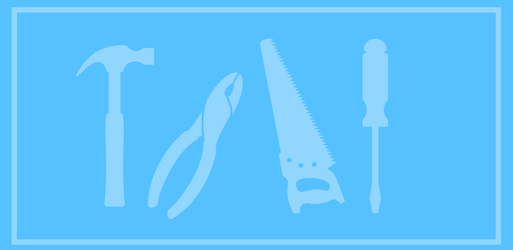
traccc

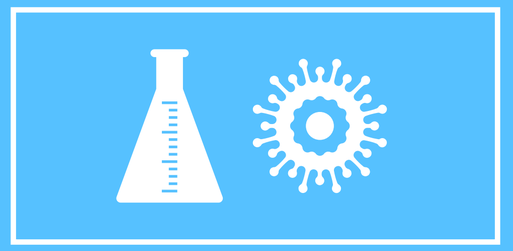
Compile-time polymorphic
geometry and material description

detray

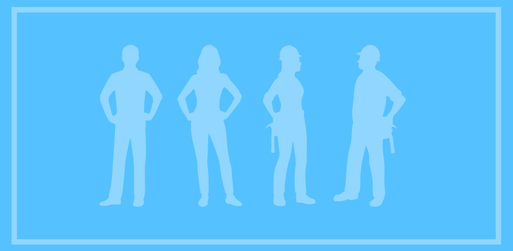
geometry & propagation







R&D PLATFORM



Compile-time polymorphic
geometry and material description

traccc

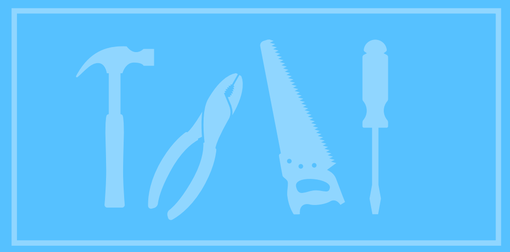
detray

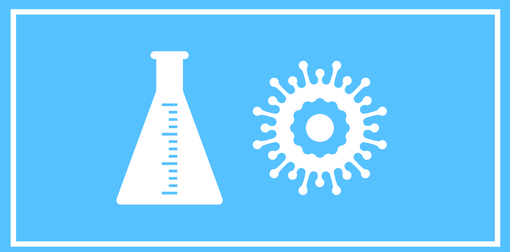
geometry & propagation

acts-project / covfie
acts-project / detray

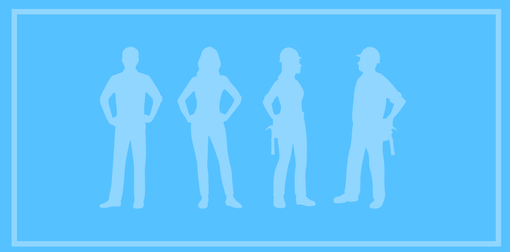
acts / Plugins
- Covfie
- Detray

Conversion for Gen2 type geometries has been showcase, Gen3 type geometry should get native conversion support into the detray description.



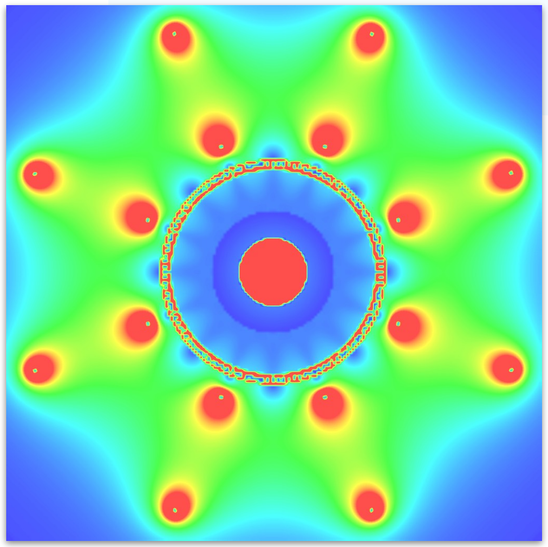


R&D PLATFORM



traccc

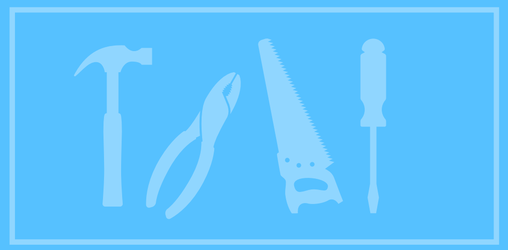
Composable generic vector field library, allows to describe complex fields on host and device.

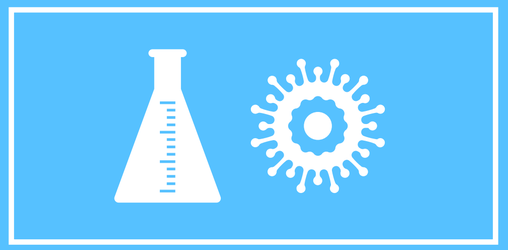


covfie

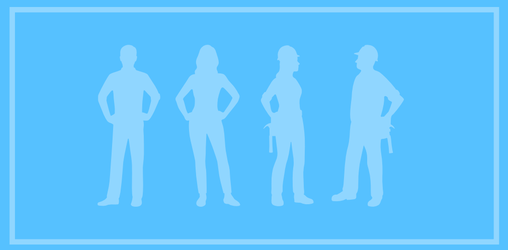
generic vector field library

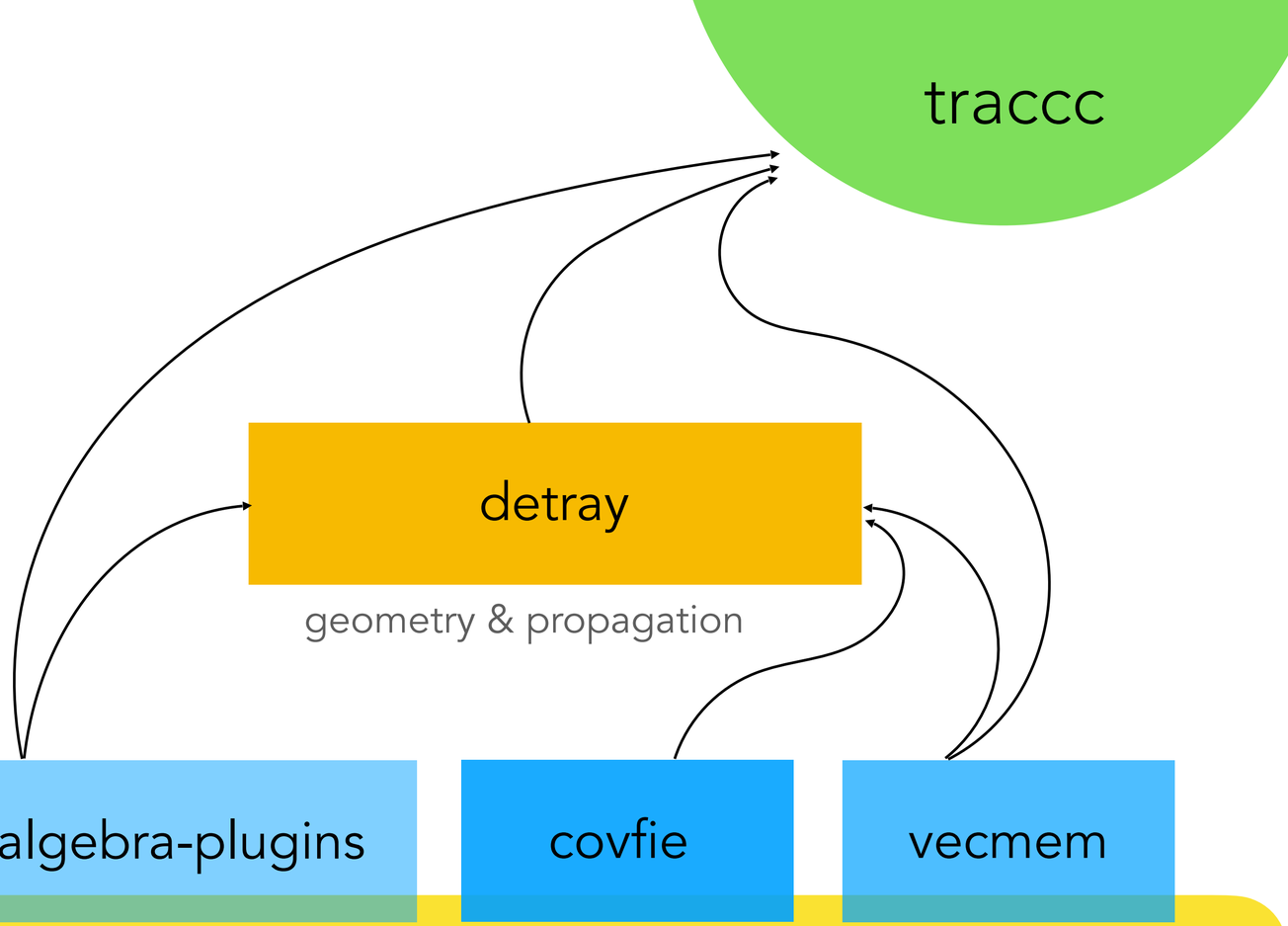
ATLAS magnetic field slice rendered on an NVIDIA GPU.





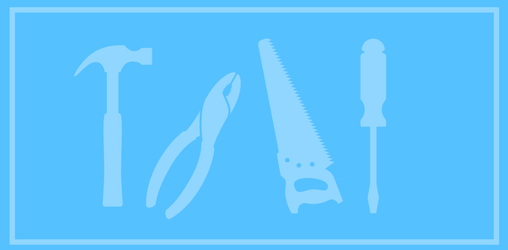
R&D PLATFORM

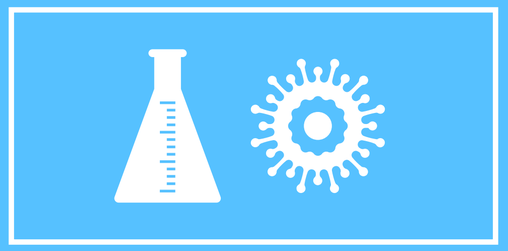




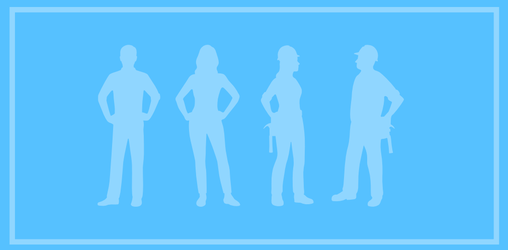
traccc was established as a stand-alone R&D project:
- conceptually following the ACTS track reconstruction concepts
- unavoidably the repos have diverged already

Long-term maintainability of two different repository structures is questionable
- re-integration of traccc into the ACTS core project and code separation into a respective CPU and GPU location is foreseen
- Level of code sharing is not yet understood

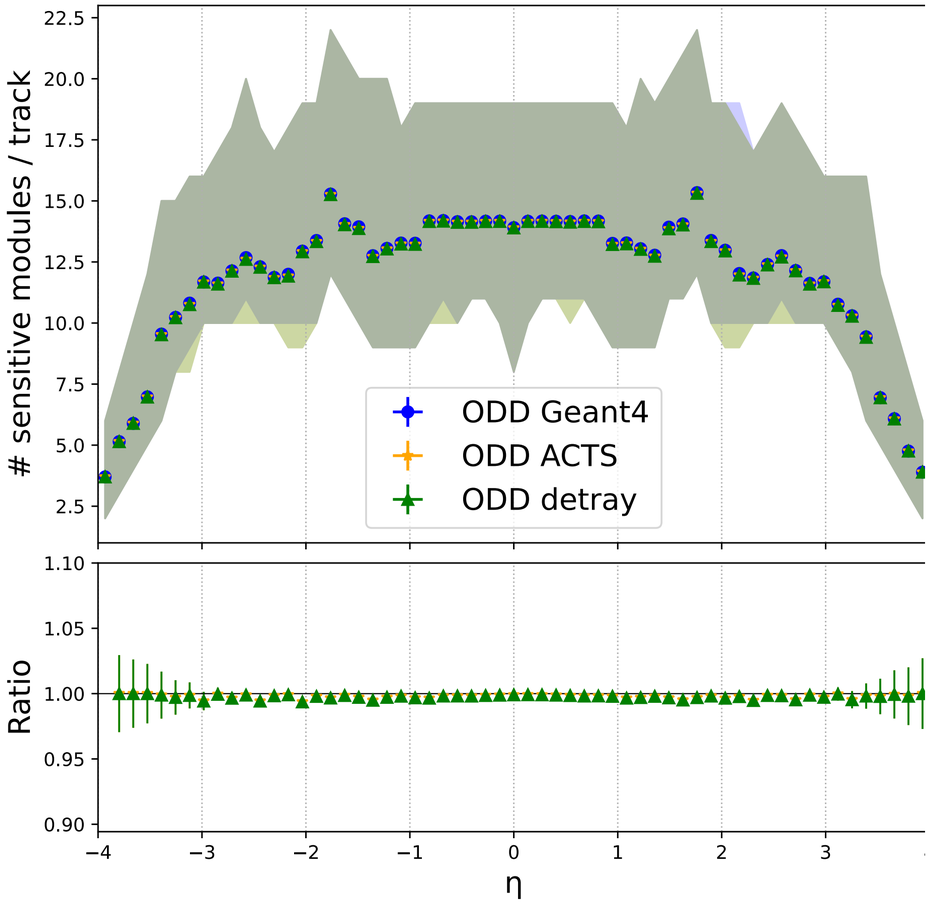




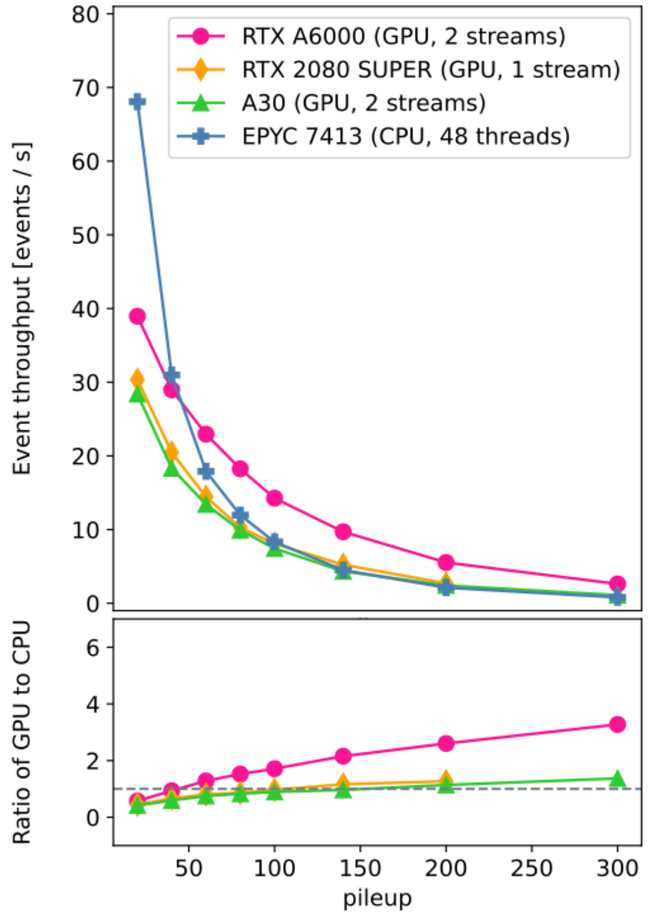
R&D PLATFORM



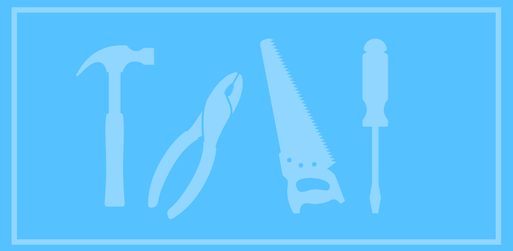
traccc

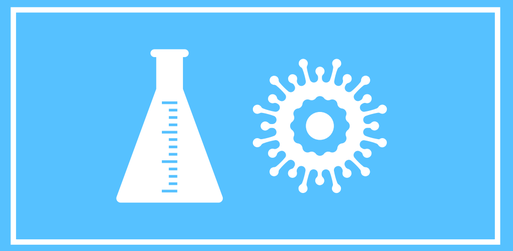


Navigation to sensitive surfaces
Open Data Detector (ODD)

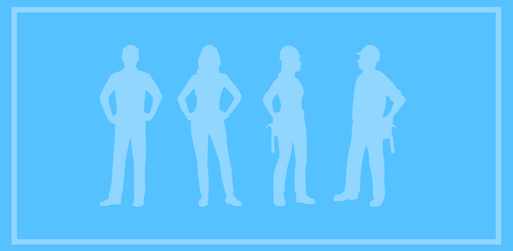


FP32 comparisons
ttbar, μ~200, ODD





R&D PLATFORM



Example framework

plug-and-play framework

ACTS ships with a **test** framework,
which is **not intended for production**

showcase how to assemble a track reconstruction chain using the tools from the toolbox

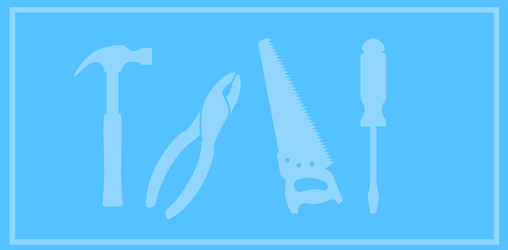
allow to easily introduce new/alternative algorithms and test them

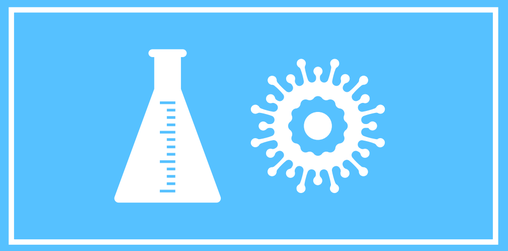
serves as a test environment for quality/performance monitoring

acts / Examples

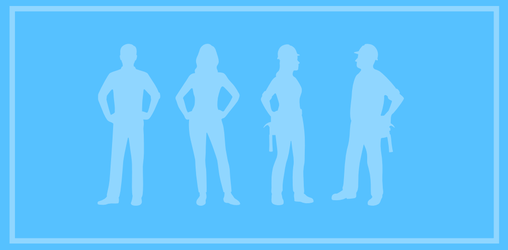
- Algorithms
- Detectors
- Framework
- Python

exemplary algorithm steering via python bindings





R&D PLATFORM

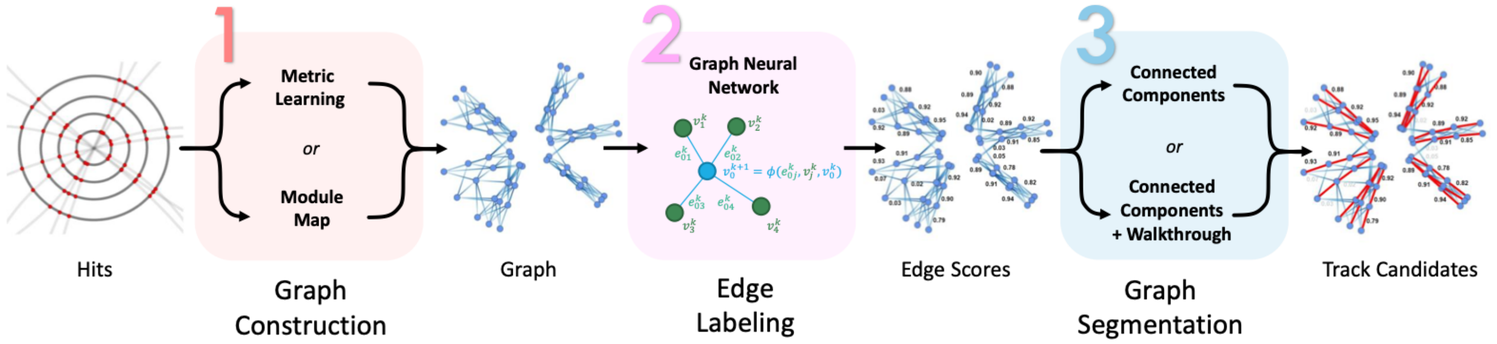


R&D Examples

plug-and-play framework

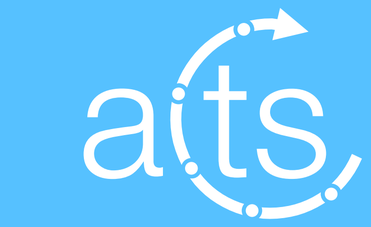
Track finding with Graph Neural Network
based on *formally known as Exa.TrkX GNN setup*

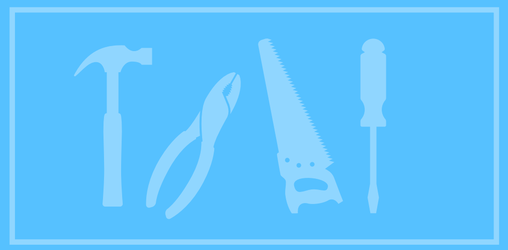
GNN chain

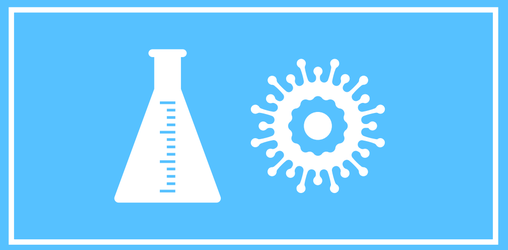


acts / Examples

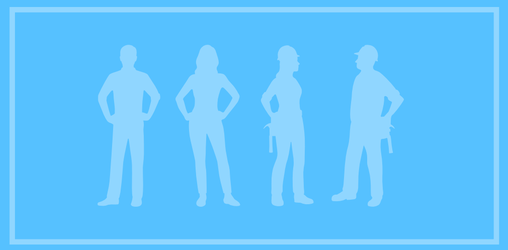
📁 Algorithms/TrackFindingExaTrkX







R&D PLATFORM

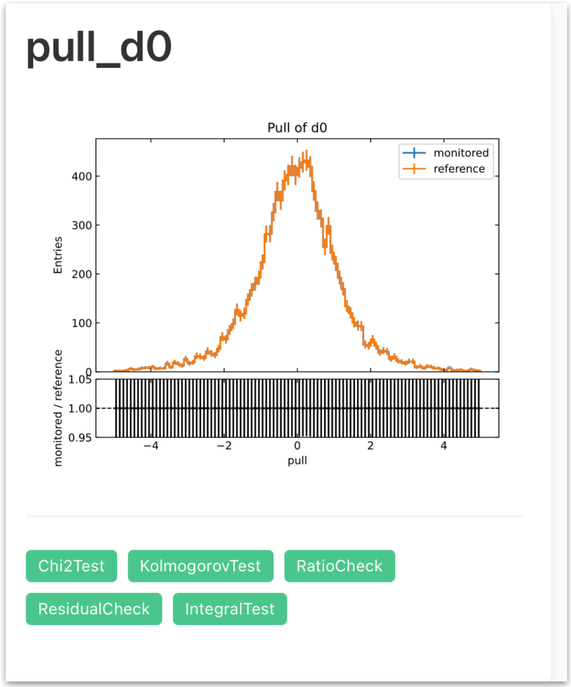


Open Data Detector and example framework

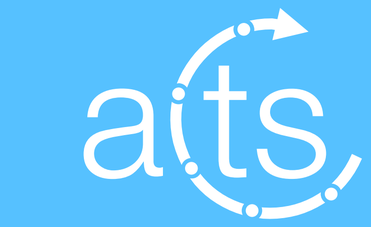
plug-and-play framework

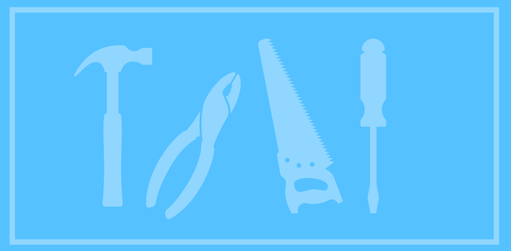
realistic test setup

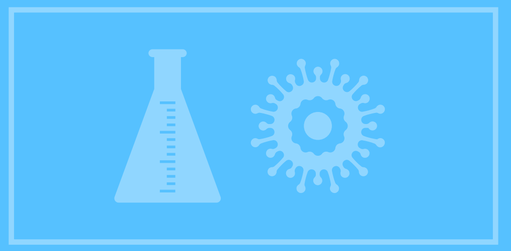
This is our main test chain showcasing a complete tracking chain:

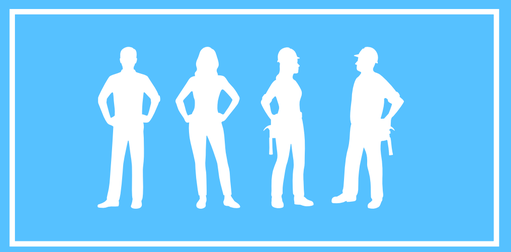


Basis of our performance testing and monitoring.









COMMUNITY

Acts

Follow

README.md

The ACTS (A Common Tracking Software) Project

The ACTS project was launched in 2016 as a feasibility study aiming to encapsulate the common and re-usable components of the ATLAS Common Tracking Software for broader use in the community. From the very beginning it was targetting at high quality, generic, modernly designed components that can be used to assemble track and vertex reconstruction applications for high energy, nuclear and heavy ion physics experiments.

The ACTS core project implements event data model, geometry, and tracking and vertexing tools in C++, following the C++20 standard, and aims at minimal dependecies for the core software stack. However, customizable extensions and interface layers to community libraries are available and can be augmented to the core package.

Project organization

ACTS is organized in a core project `acts-project/acts` which holds the software components and a simple example/demonstration framework that showcases typical track reconstruction applications using the OpenDataDetector.

Furthermore, it hosts an umbrella project, called `traccc` that aims to re-implement the standard `Acts` chain for massively parallel hardware. `traccc` relies on the sub libraries:

- vecmem: a library for the memory management of containers
- covfie: a covariant vector field library, e.g. for the description of the magnetic field
- detray: a GPU friendly geometry library for describing the reconstruction geometry
- algebra-plugins: an abstraction layer for linear algebra and float precision

Supported by

R&D on EXPERIMENTAL TECHNOLOGIES	CERN EP R&D	The CERN EP department has launched a strategic R&D programme on technologies for future experiments. This initiative covers detector hardware, electronics, software and detector magnets for new experiments and detector upgrades beyond LHC phase II.
iris hep	IRIS-HEP	IRIS-HEP is a software institute funded by the National Science Foundation. It is developing state-of-the-art software cyberinfrastructure required for the challenges of data intensive scientific research at the High Luminosity Large Hadron Collider (HL-LHC) at CERN, and other planned HEP experiments of the 2020's.
AIDA Innova	AIDAInnova	Discoveries in particle physics are technology-driven; AIDAinnova will provide state-of-the-art upgrades to research infrastructures, such as test beams, in order to unfold the scientific potential of detector technologies. The project will run for a duration of four years from April 2021 to March 2025 and is co-funded by the European Commission under its Horizon 2020 programme.
NexTGen	CERN NextGen Triggers	The Next Generation Triggers project, or NextGen, started in January 2024 as a collaboration between CERN (the Experimental Physics, Theoretical Physics and Information Technology Departments) and the ATLAS and CMS experiments funded by the Eric and Wendy Schmidt Stratic Fund for Fundamental Research. The key objective of the five-year NextGen project is to get more physics information out of the HL-LHC data.

View as: Public

You are viewing the README and pinned repositories as a public user.

Get started with tasks that most successful organizations complete.

Discussions

Set up discussions to engage with your community!

Turn on discussions

People

View all

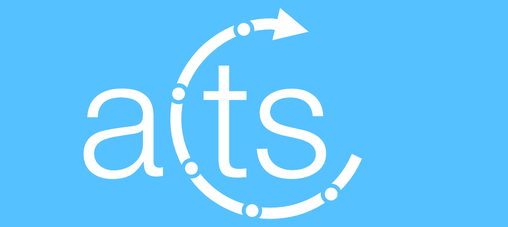
Invite someone

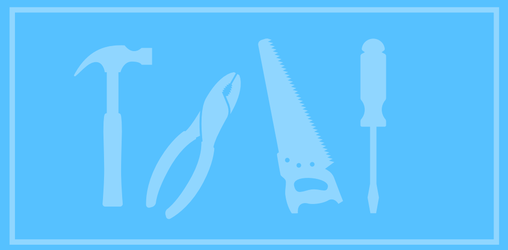
Top languages

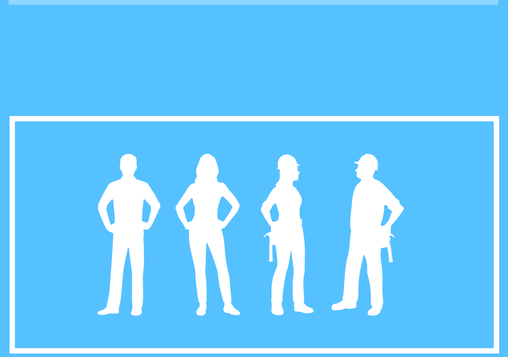
C++ Python TeX TypeScript Dockerfile

Most used topics Manage

particle-track-reconstruction physics-experiment reconstruction simulation

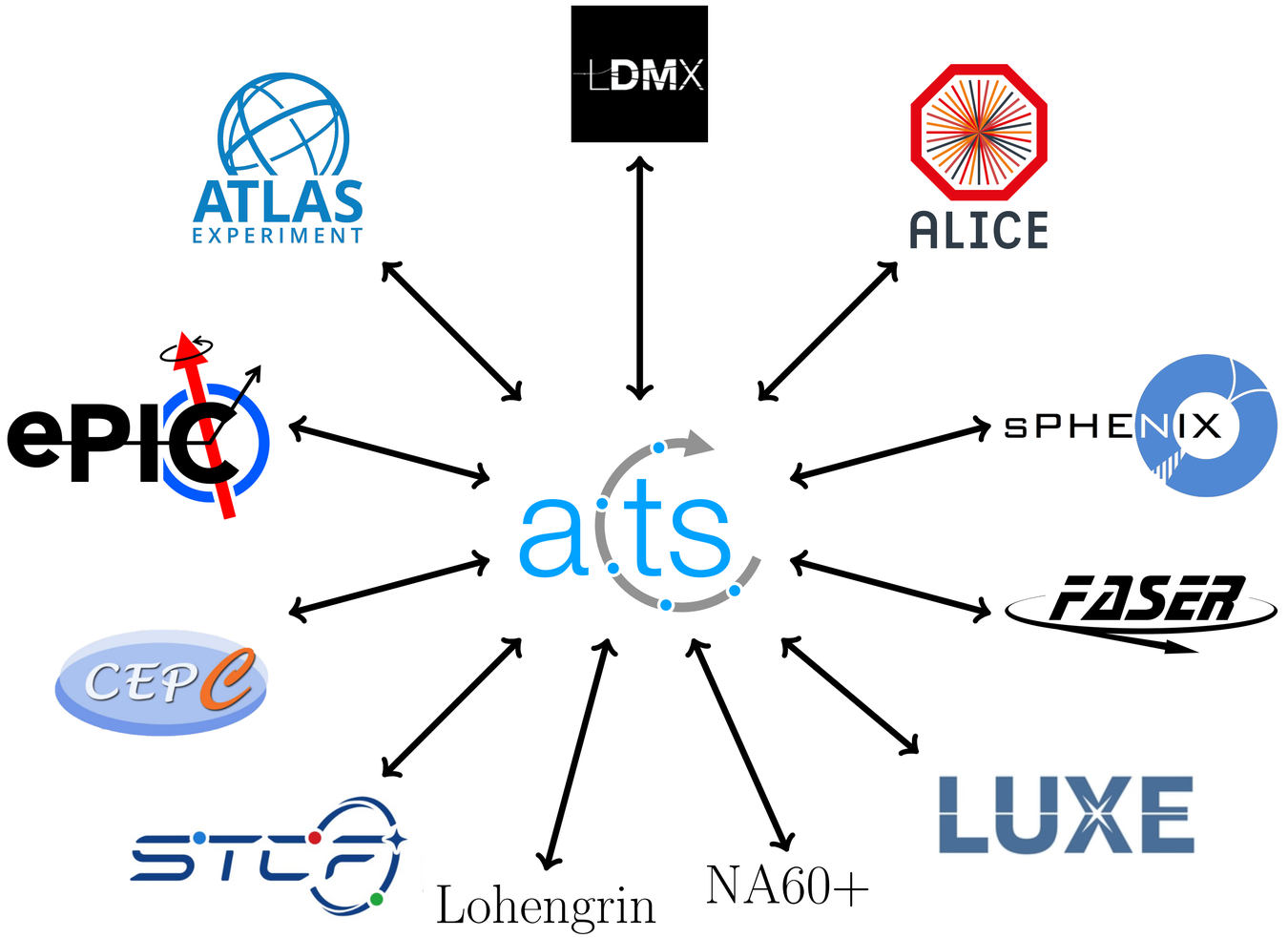


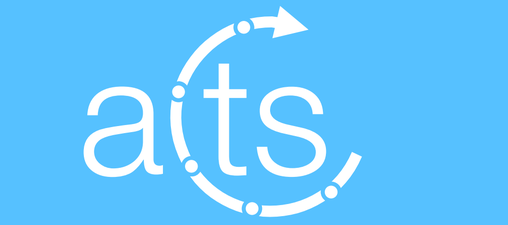


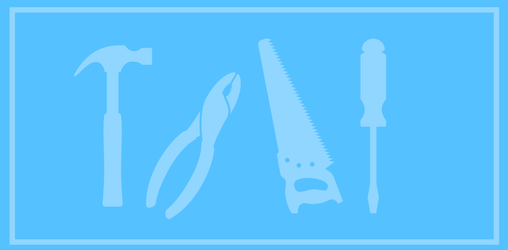


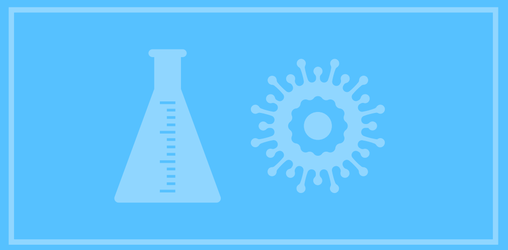
COMMUNITY

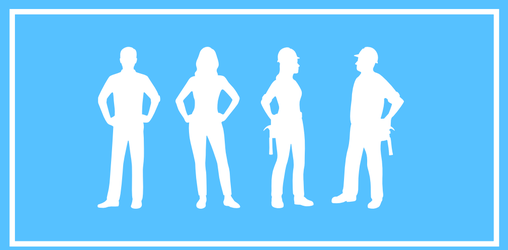
Experiment landscape





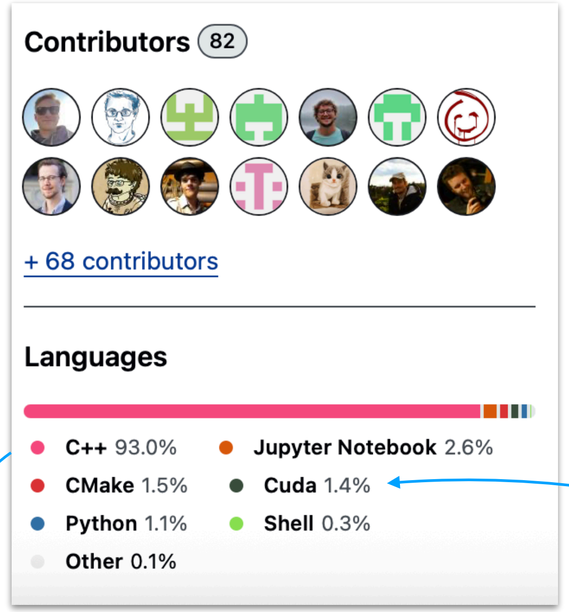






COMMUNITY

Developer book

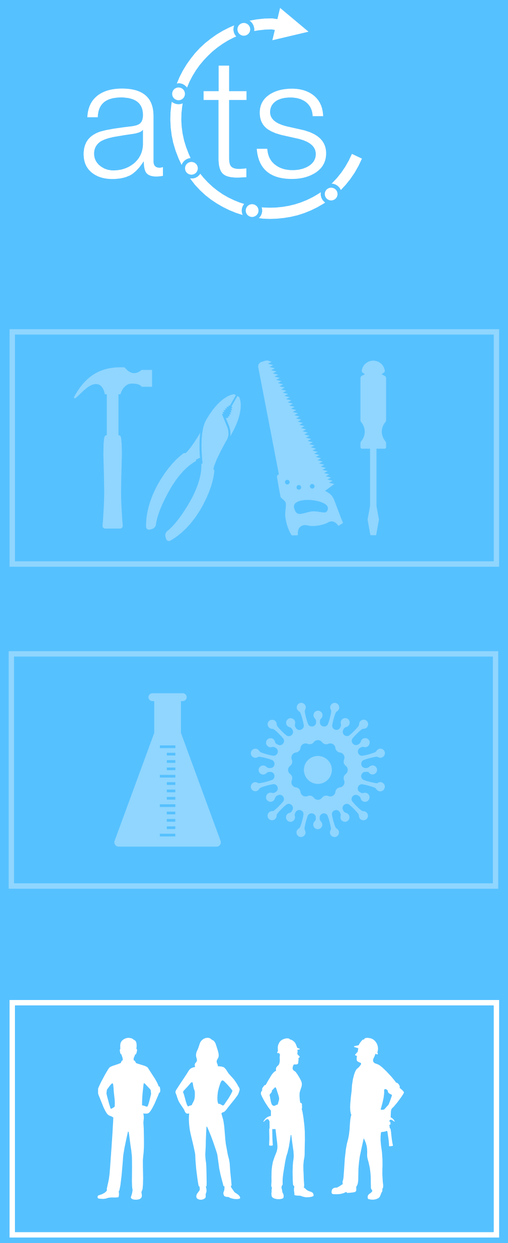


Core project has :

- 82 different contributors
- 186 forks
- 346 unique cloners
- 115 stars
- 3200 merged pull requests

Fully C++20 compliant

See discussion about future and structure of traccc.



Community - Contributing

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

Clone:

https://github.com/<username>/acts

Make an Issue / PR:

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

Ask on mattermost:

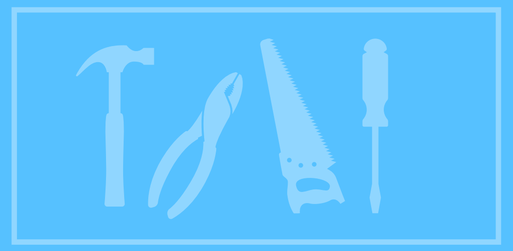
https://mattermost.web.cern.ch/acts/channels/town-square

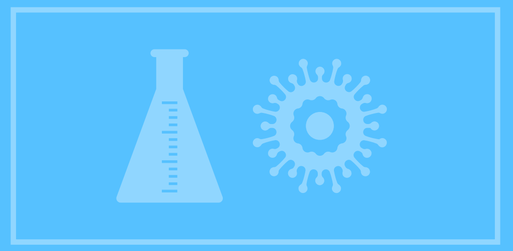
Tuesday 17:00, CE(S)T

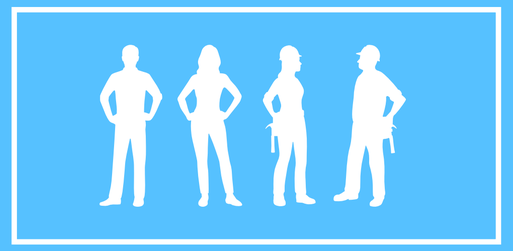
Discuss at the
open develops meeting

https://indico.cern.ch/category/7968/

occasional Asia-friendly time slot 9:00 CE(S)T







COMMUNITY

Community - Contributing

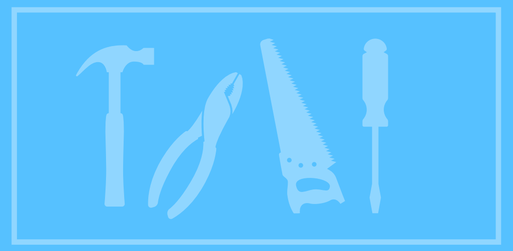
Solid development program needs some conventions and rules

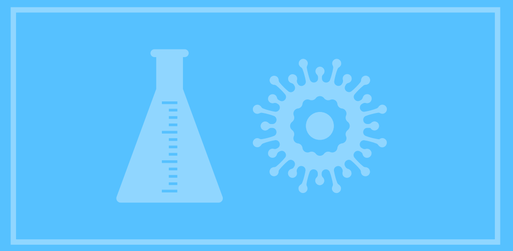
<u>Code quality & style:</u>

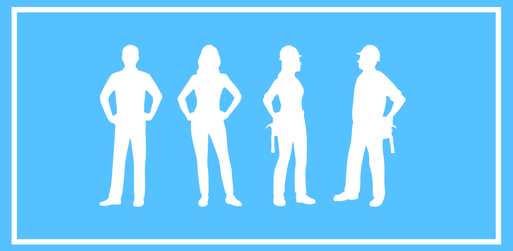
Several checks in place that run automatically on PRs

```
▸ Run pre-commit run --all-files --show-diff-on-failure
clang-format.....................................................Passed
Trim Trailing Whitespace.........................................Passed
Fix End of Files.................................................Passed
Check Yaml.......................................................Passed
Check for added large files......................................Passed
black-jupyter....................................................Passed
gersemi..........................................................Passed
codespell........................................................Passed
license..........................................................Passed
include_guards...................................................Passed
pragma_once......................................................Passed
type_t...........................................................Passed
boost_test.......................................................Passed
cmake_options....................................................Passed
Leftover conflict markers........................................Passed
math_macros......................................................Passed
codegen_dependencies.............................................Passed
```

Format, style, conventions, spelling using a **pre-commit** check







COMMUNITY

Community - Contributing

Solid development program needs some conventions and rules

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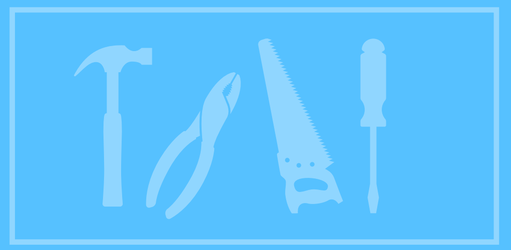
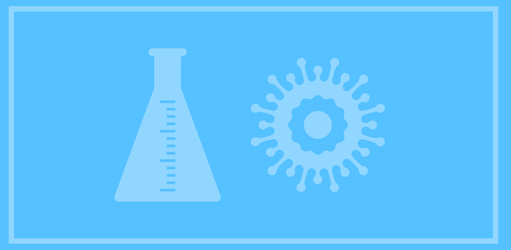
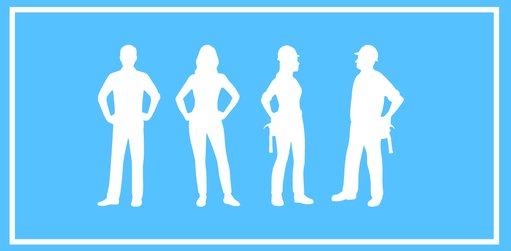
Static code analyzer using **sonarcloud**







COMMUNITY

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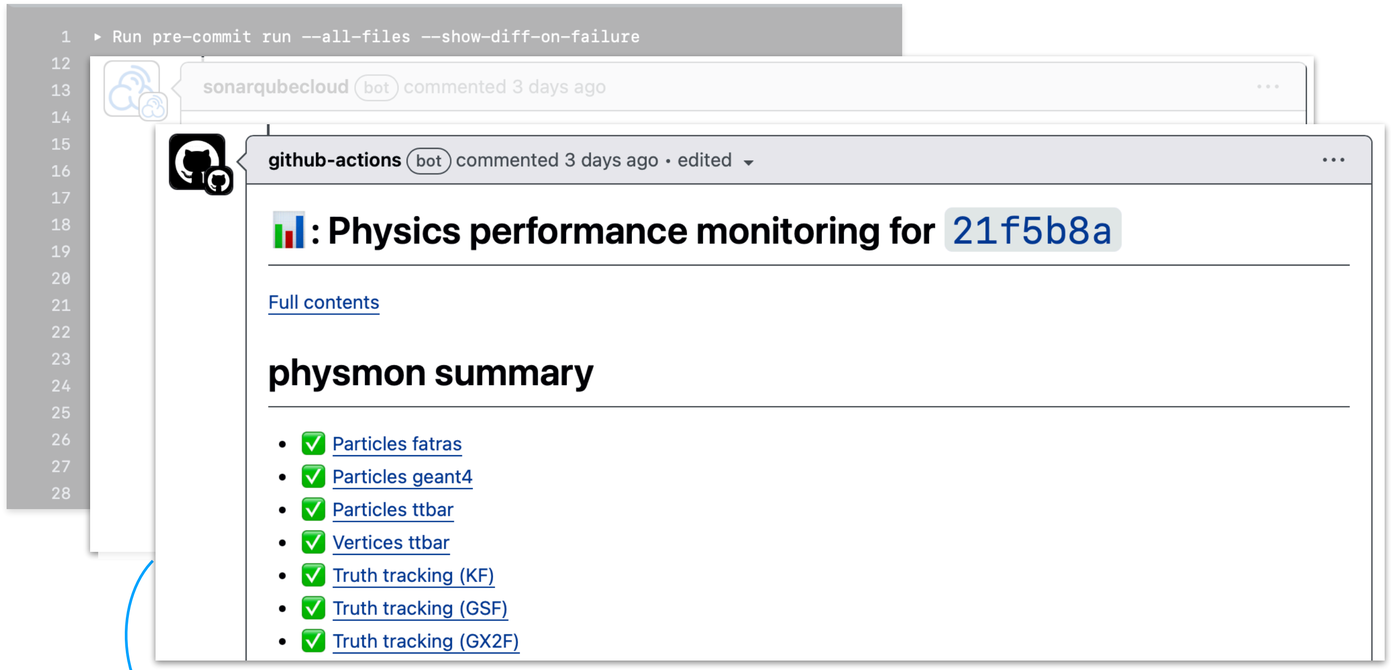
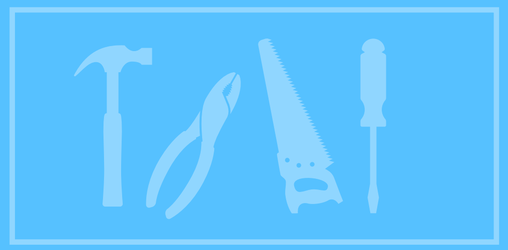
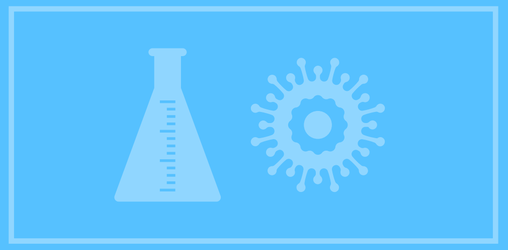
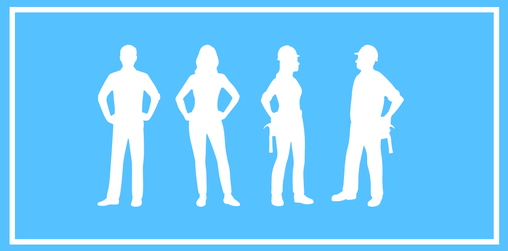


Performance monitoring & regression tests.







COMMUNITY

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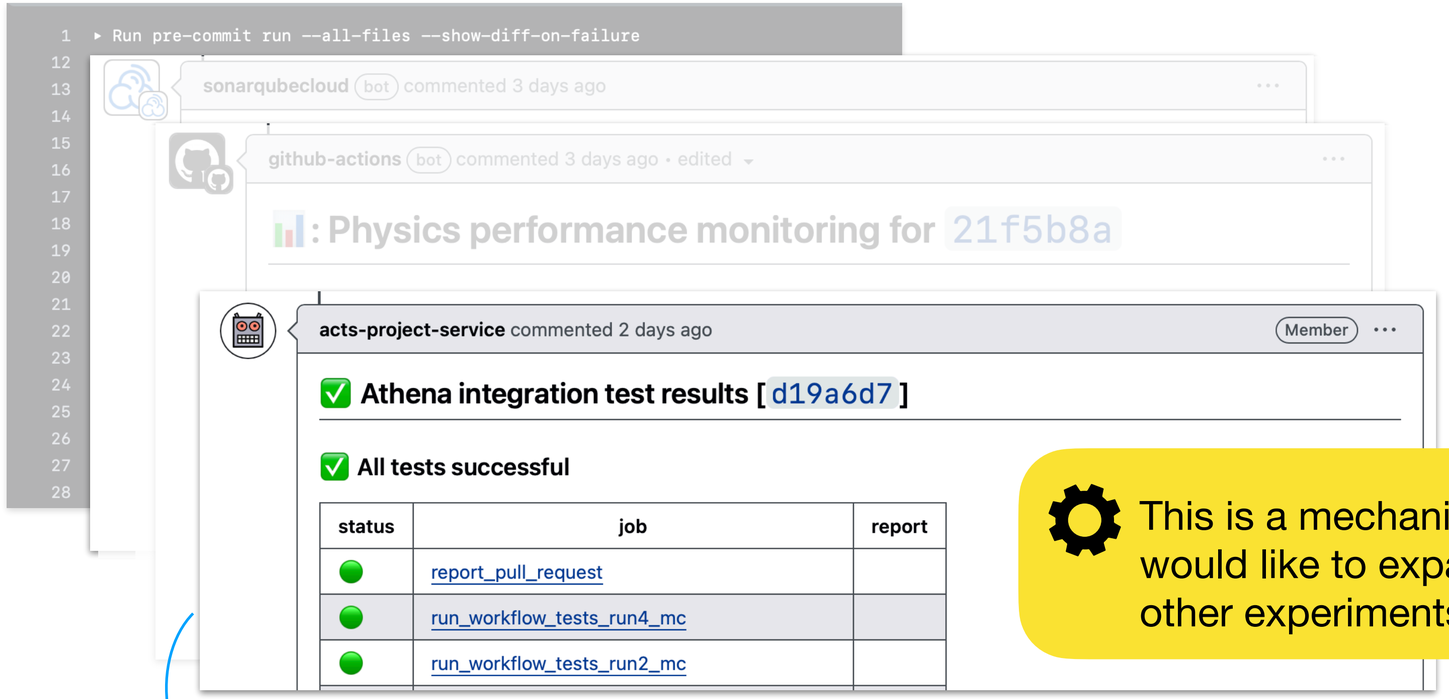
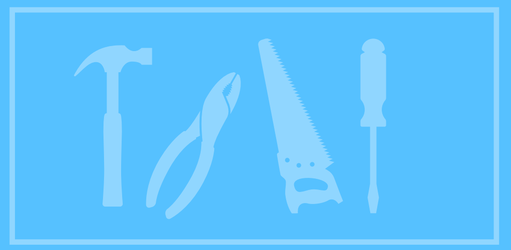
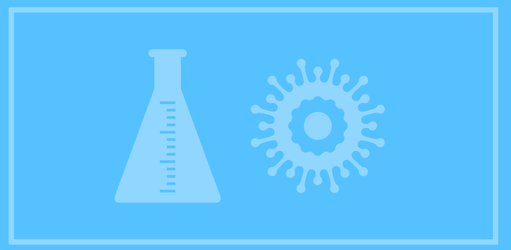
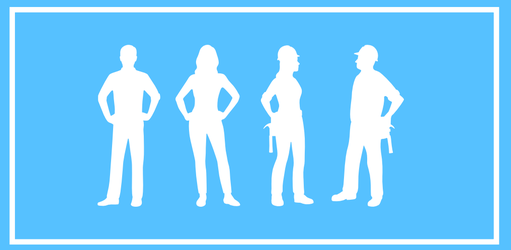


This is a mechanism we would like to expand to other experiments.

Dedicated ATLAS integration tests







COMMUNITY

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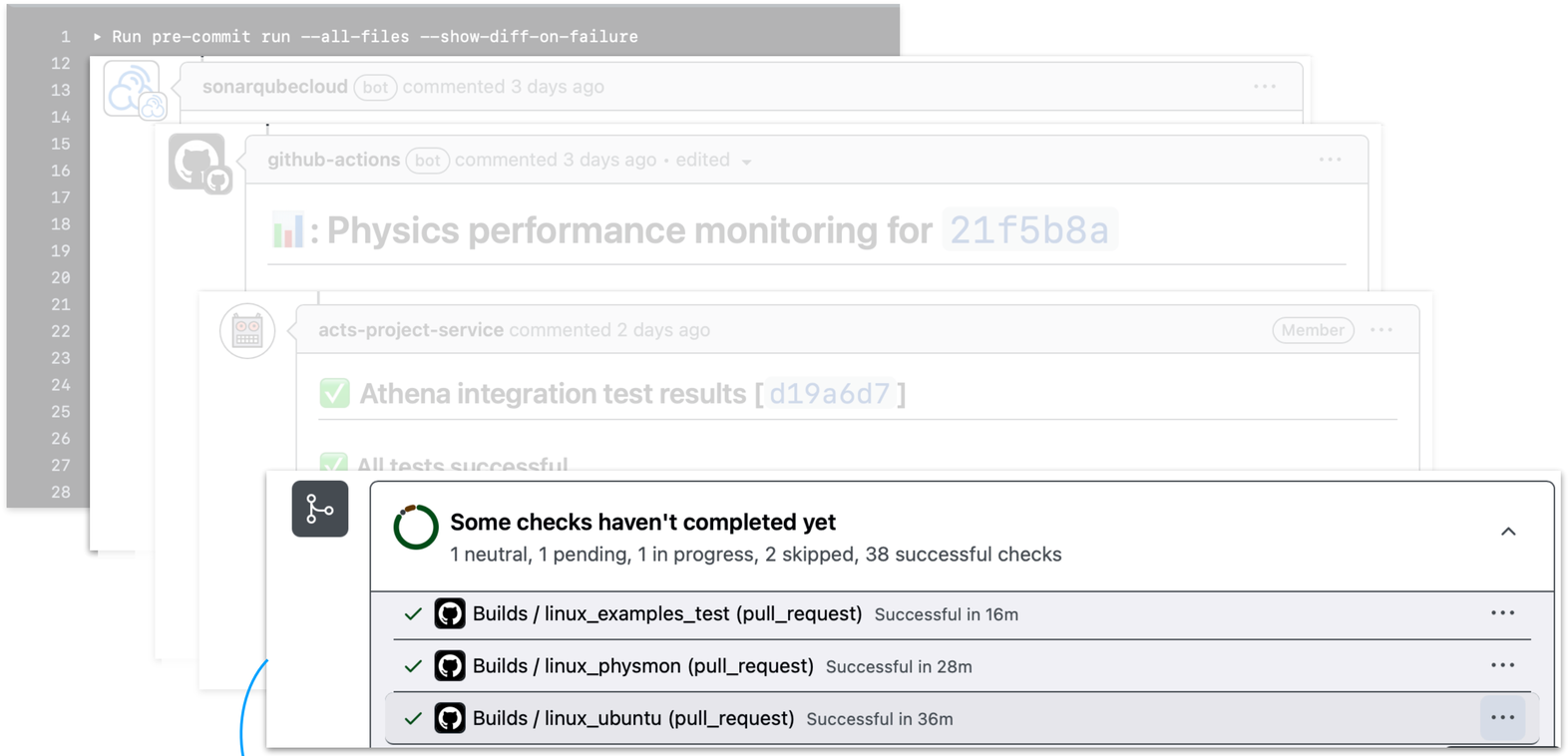


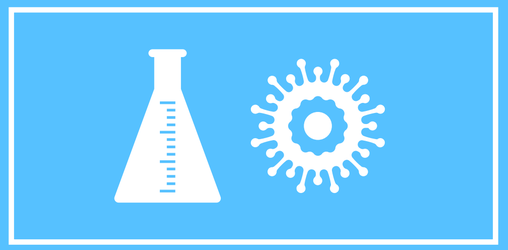
Unit and python level tests on PRs.

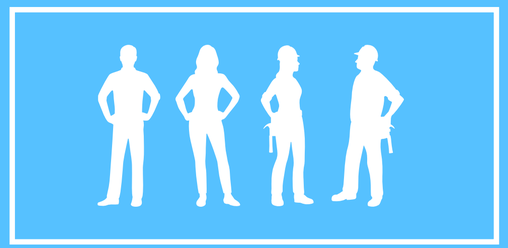
Community - Governance

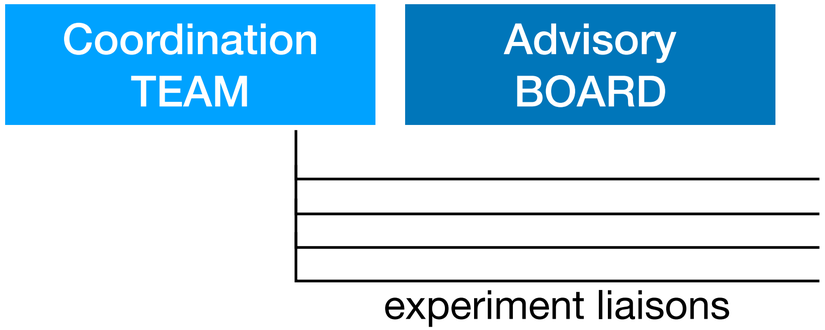
Give the project a lightweight structure:

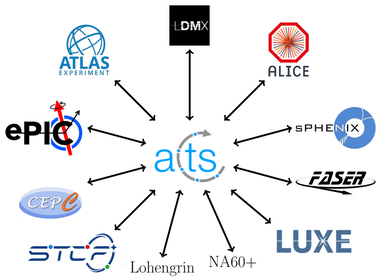
- first proposal of project organization in Nov 2024 (ACTS WS)
- revised this to a white paper document in the meantime


TOOLBOX


R&D PLATFORM


COMMUNITY





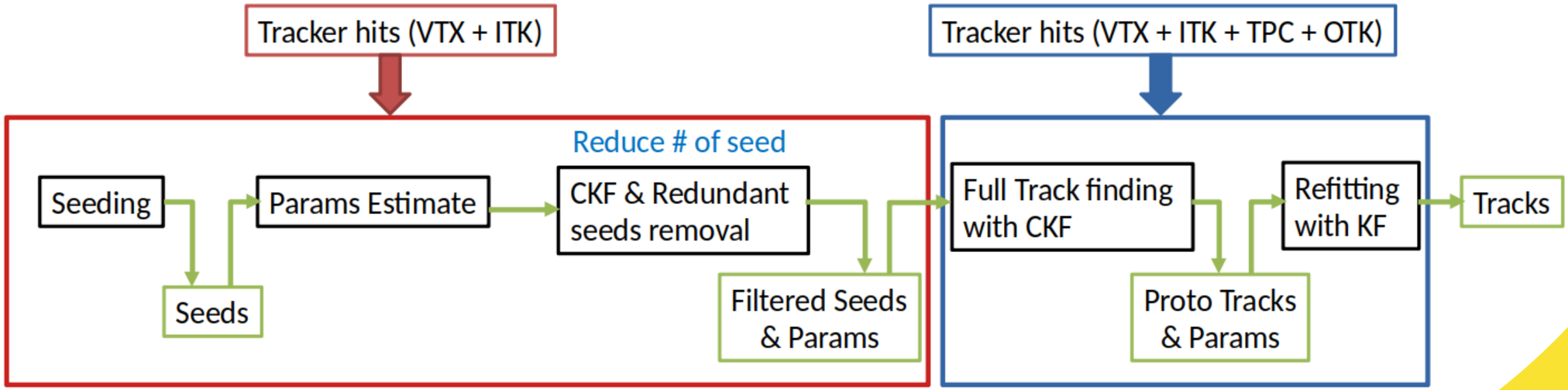
Stay tuned, first version for comments to be circulated very soon.

ACTS Tracking chain for CEPC

Track finding implemented in two steps

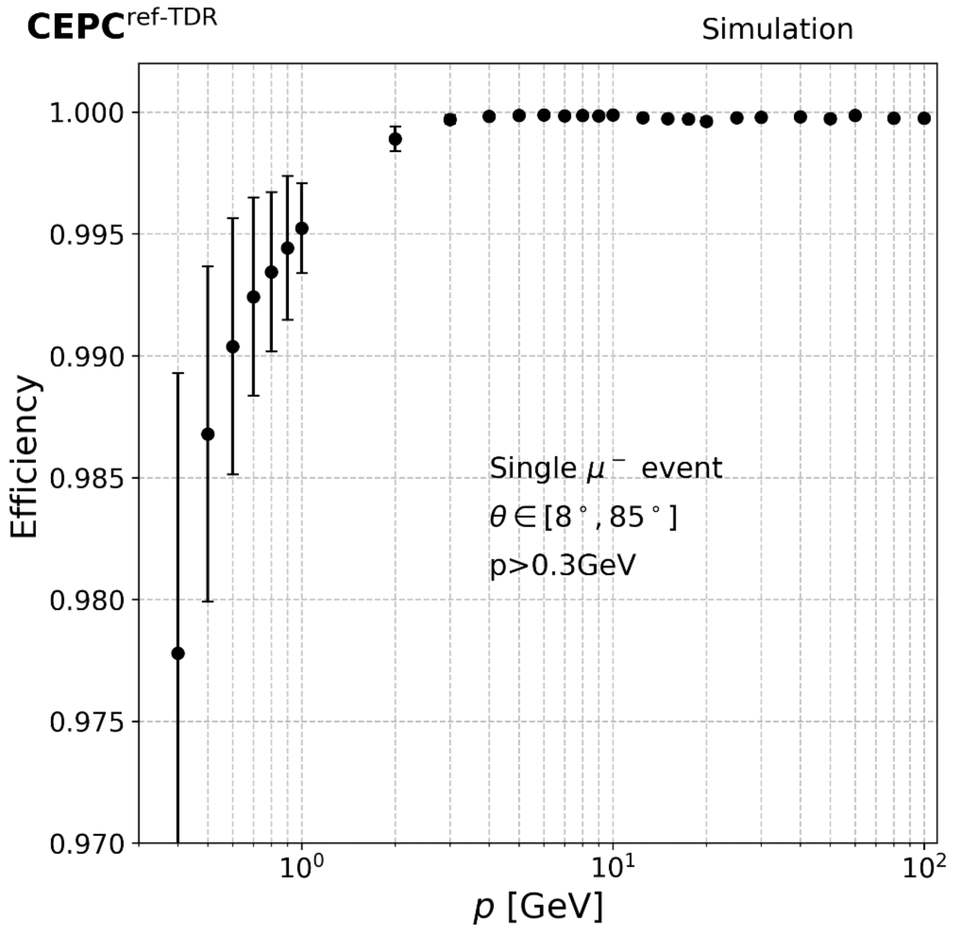
- Silicon track finding: VTX + ITK
  - Seeding in VTK + ITK (9 layers) ~ 80 triples/particle
  - Duplicate seed removal and successive CKF track finding

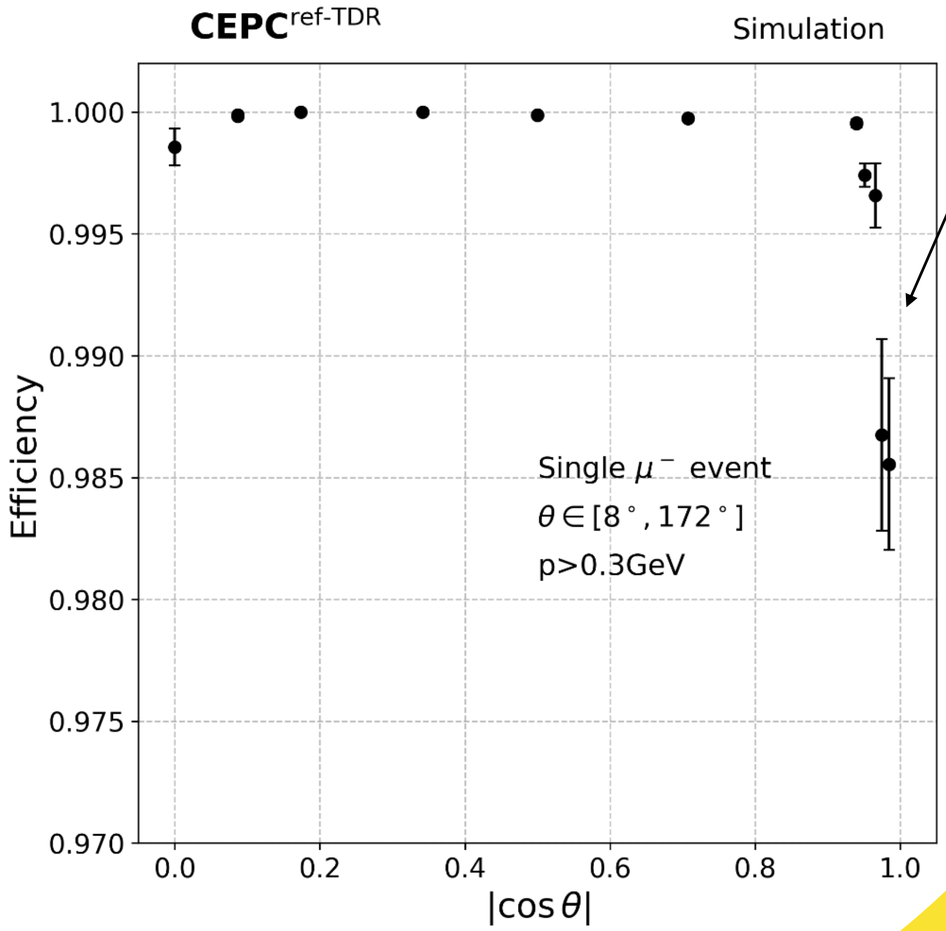
- Full tracking: VTX + ITK + TPC + OTK
  - With filtered seeds & parameters from Silicon track finding



ACTS Tracking chain for CEPC

μ Tracking efficiency (“Technical efficiency”)

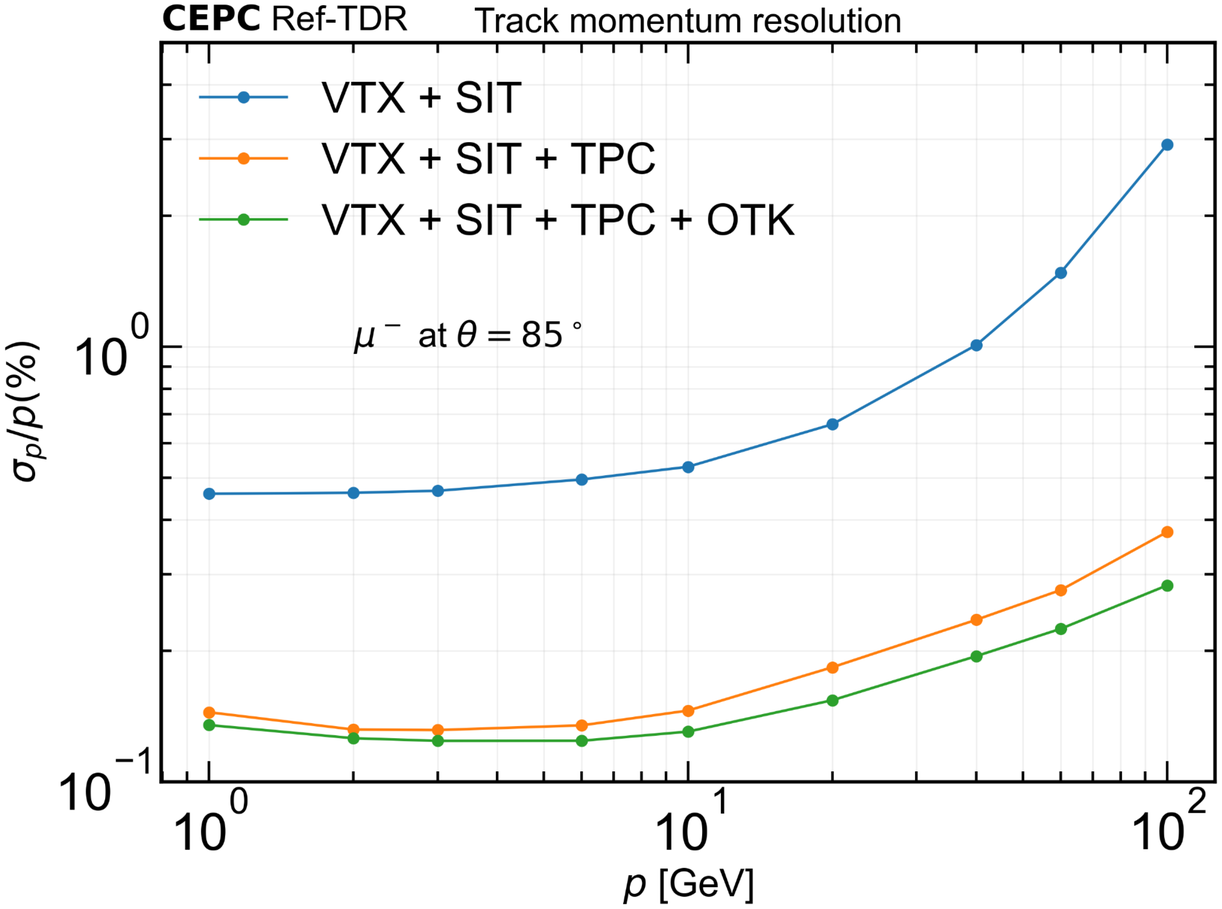


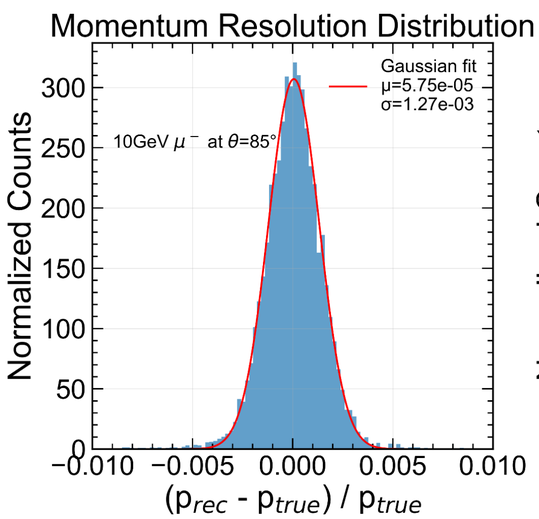


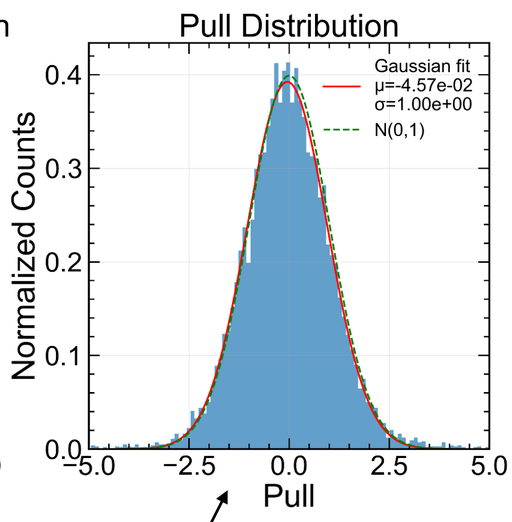
membrane cathode spanned between two rings in the center of the TPC

ACTS Tracking chain for CEPC

μ resolution at different momenta



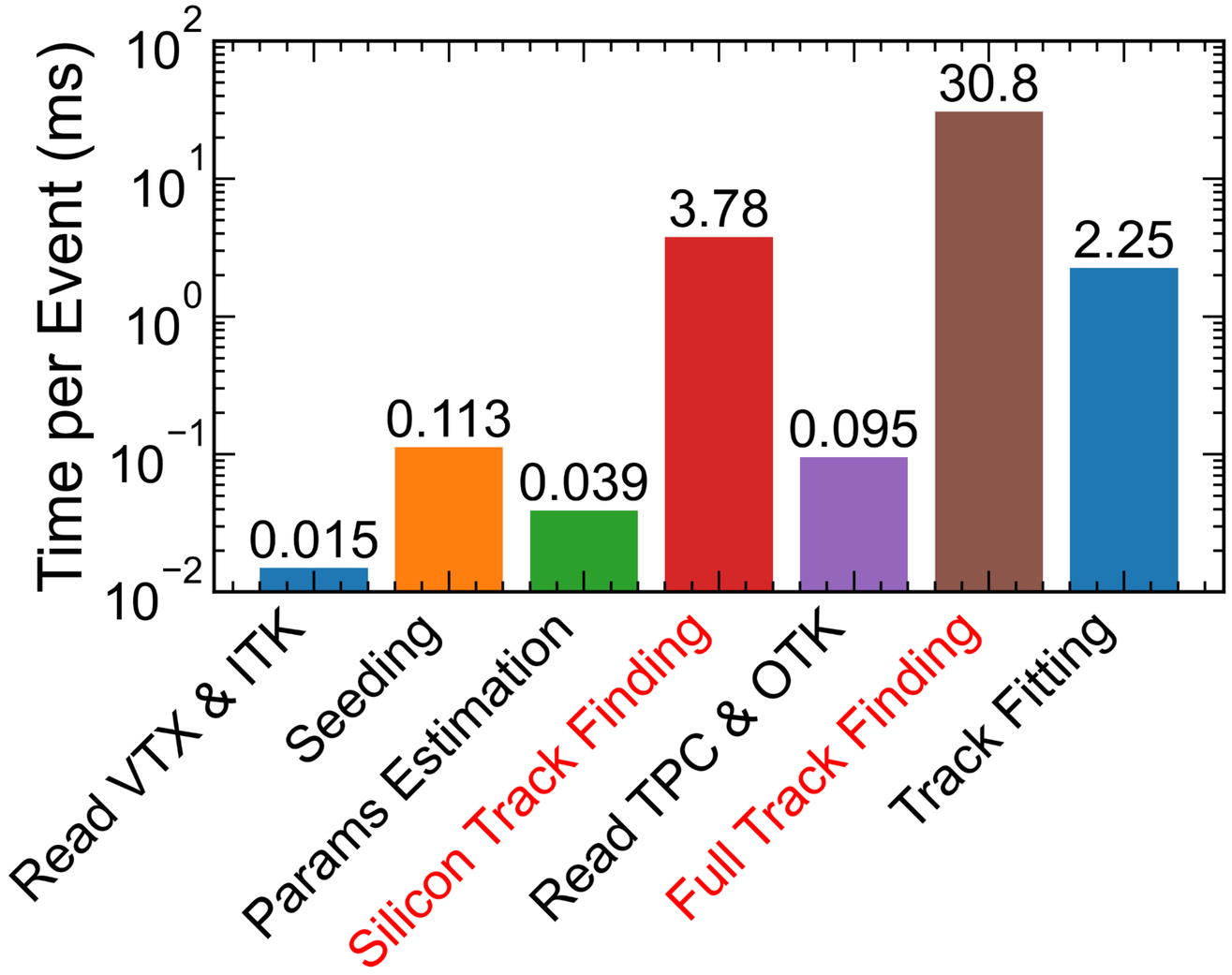


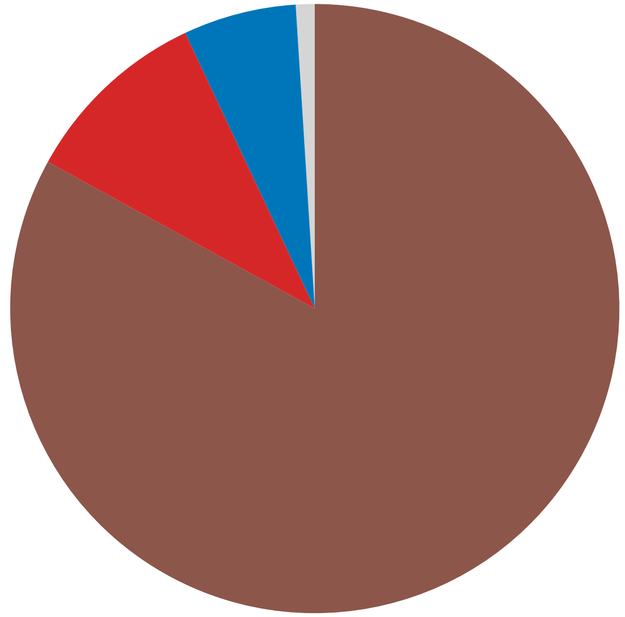


Good control of the errors

ACTS Tracking chain for CEPC

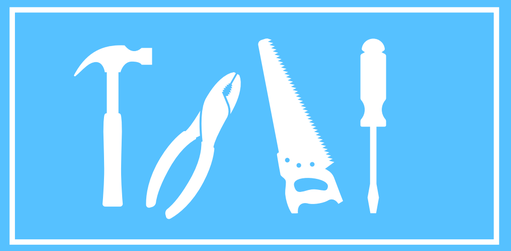
Computing performance



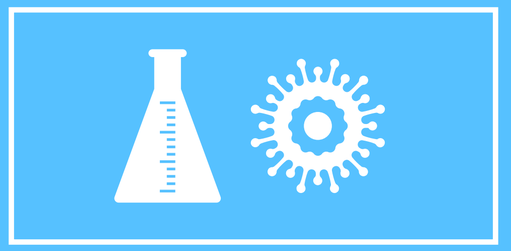


Tested with single thread at:

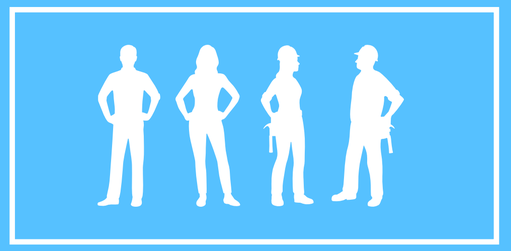
- Intel(R) Xeon(R) Silver CPU 4214 @ 2.20GHz



TOOLBOX



R&D PLATFORM



COMMUNITY

Concluding remarks

ACTS has matured as a toolkit

- sPHENIX , FASER, LUXE are running in data taking mode
- ATLAS Phase-2 track reconstruction is fully based on it
  (Run-3 vertex reconstruction is ACTS based)
- List of features and tools is constantly increasing

Several R&D projects within the ACTS ecosystem

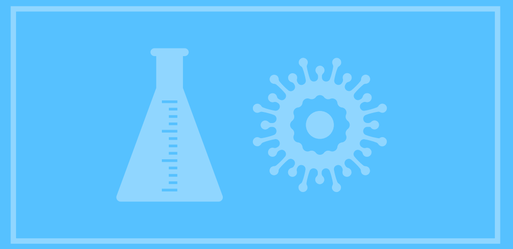
- prominent: GPU R&D line traccc
- GNN based tracking available

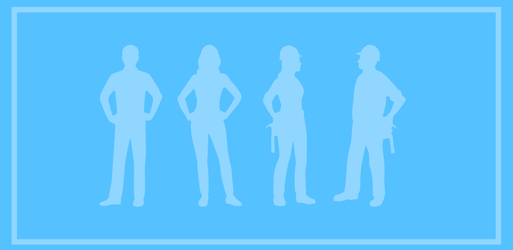
Community is growing

- recent, strong interest from the nuclear physics community
- will be distilled into a governance document soon

Join. Contribute. Collaborate.

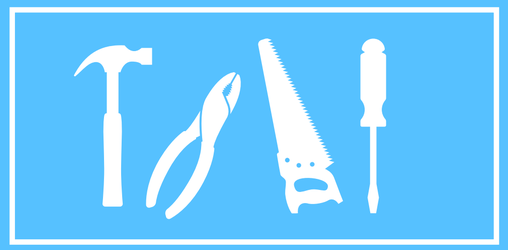
… a lot of backup slides ahead …



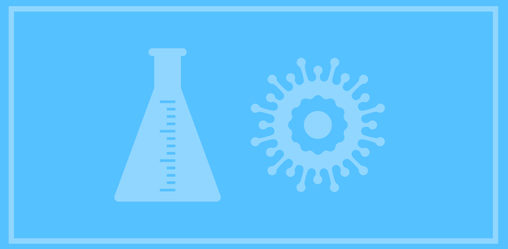


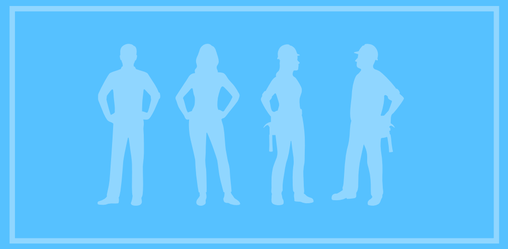
What is in the toolbox?

Geometry & Material



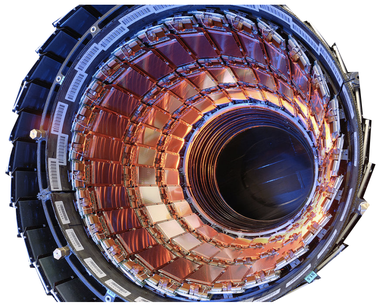
TOOLBOX



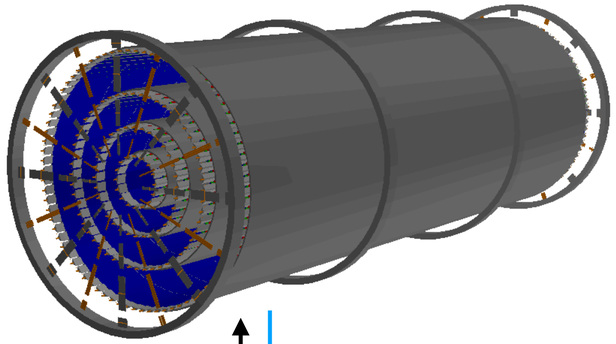


Experiment description

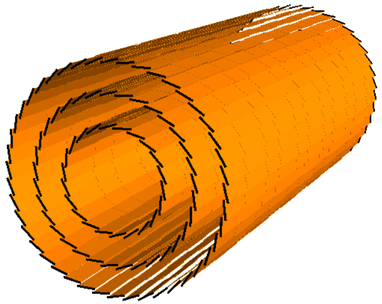
Reality



Full simulation



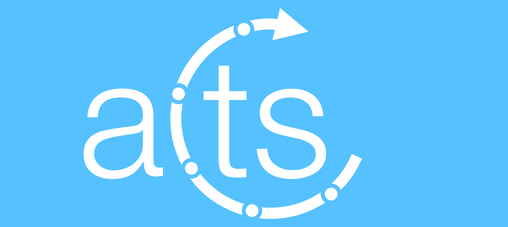
Reconstruction

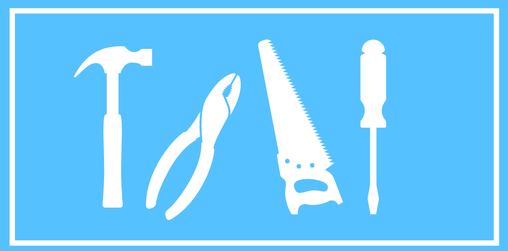


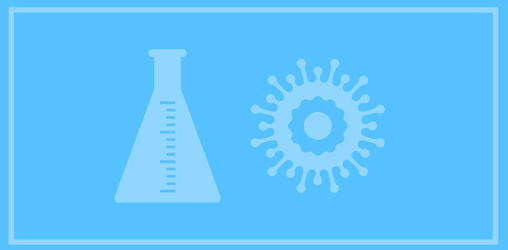
Relatively detailed description
using a 3D geometry modeller
(DD4hep, TGeo, GeoModel)
usually interfaced to Geant4

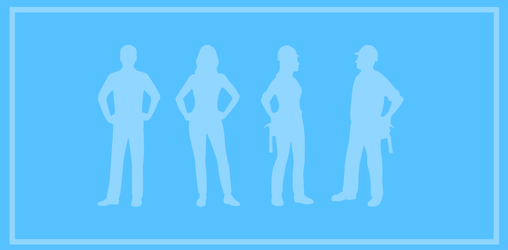
Geometry building in ACTS:

- representing sensitive surfaces
- simplifying material

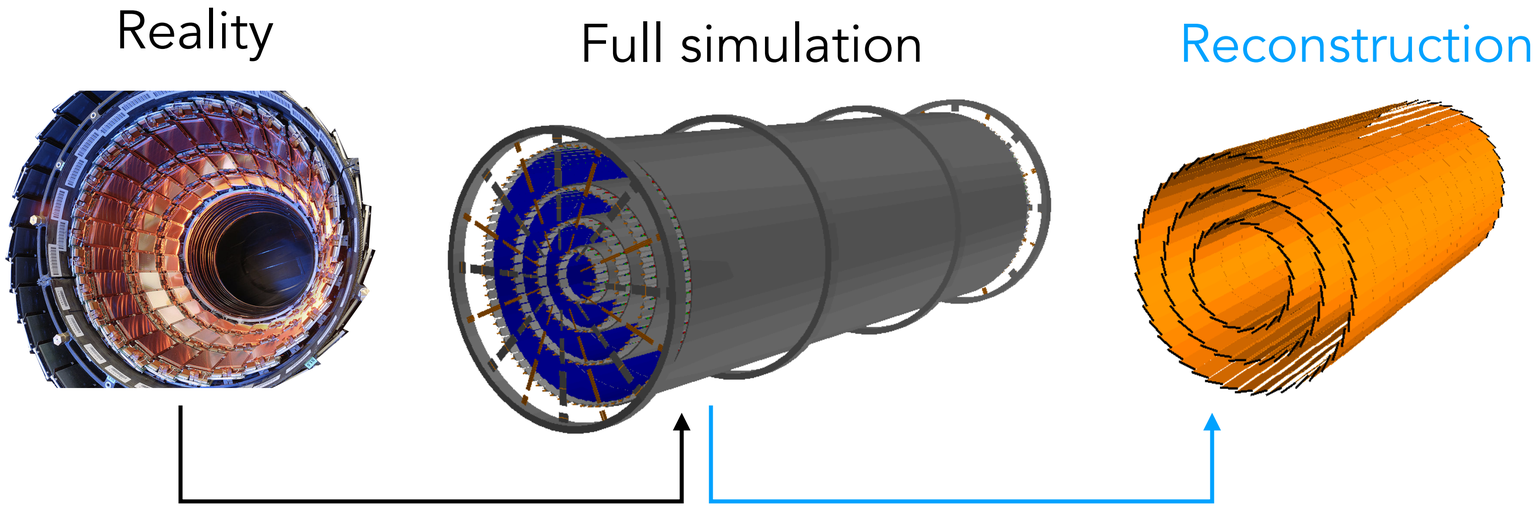








Experiment description

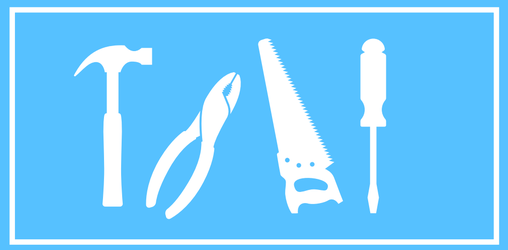


acts / Plugins

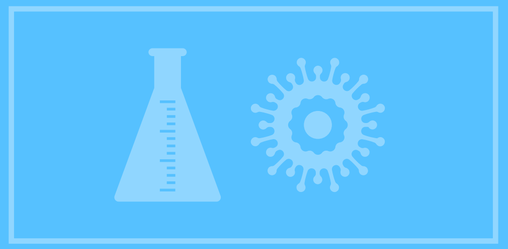
- Geant4
- GeoModel
- DD4hep
- TGeo

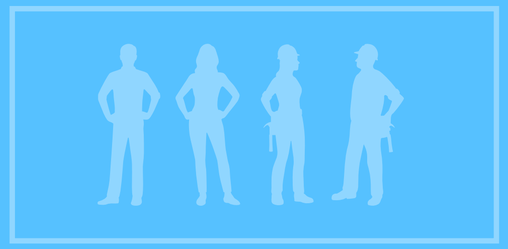
acts / Core / include / Acts

- Definitions
- Geometry
- Material
- Surfaces



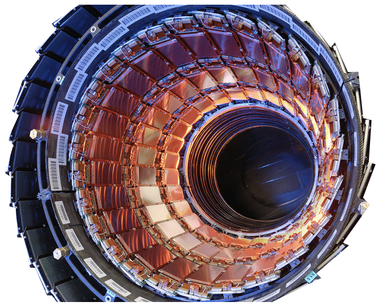
TOOLBOX



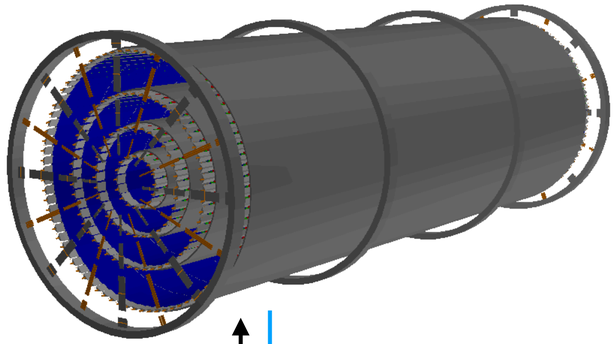


Experiment description

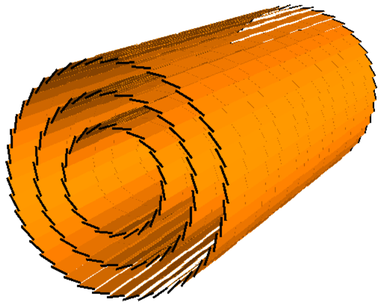
Reality



Full simulation



Reconstruction

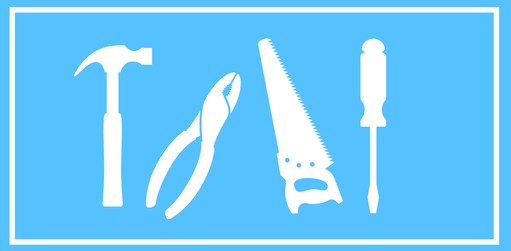


Relatively detailed description using a 3D geometry modeller (DD4hep, TGeo, GeoModel) usually interfaced to Geant4

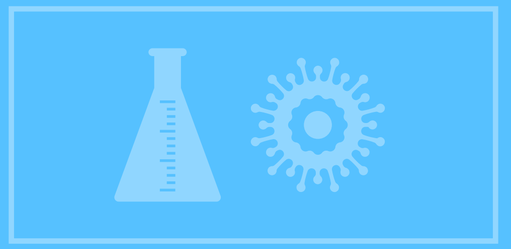
Geometry building in ACTS:

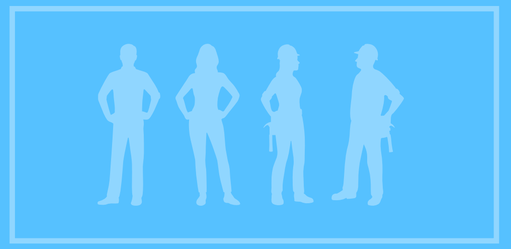
- representing sensitive surfaces
- simplifying material

ACTS material mapping mechanism



TOOLBOX





Experiment description: **geometry**

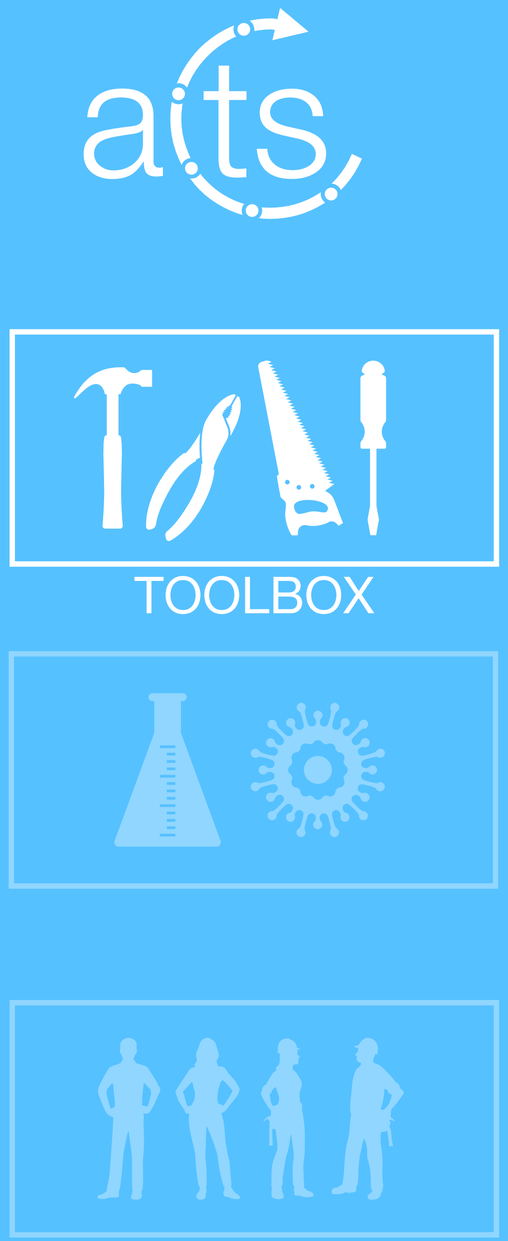
Core concept of ACTS geometry is the `Surface` class

- **all** higher level geometry objects are composed of those
  - Gen1 geometry: BoundarySurface, Layer, Volume
  - Gen2/3 geometry: Portal, Volume
- makes them reachable and navigable

We are in the process of changing to the **Gen3** geometry description:
- omission of layers in favor of layer volumes
- composable building instructions with blueprint nodes
- customizable navigation structure
- built-in support for GPU geometry model (detray)

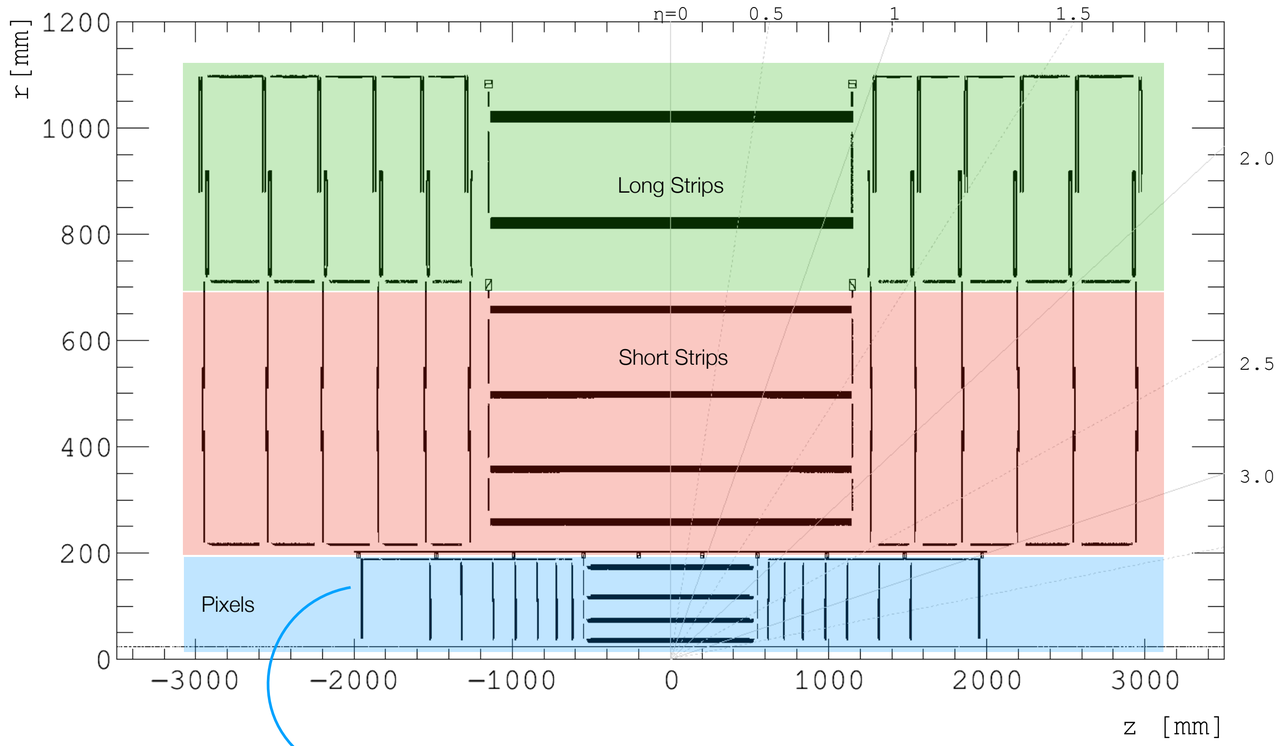
acts / Core / include / Acts

- Geometry
- Surfaces



Experiment description: material

(1) Recording the material using Geant4



High statistics tomography of detector
(recording position and properties of material)

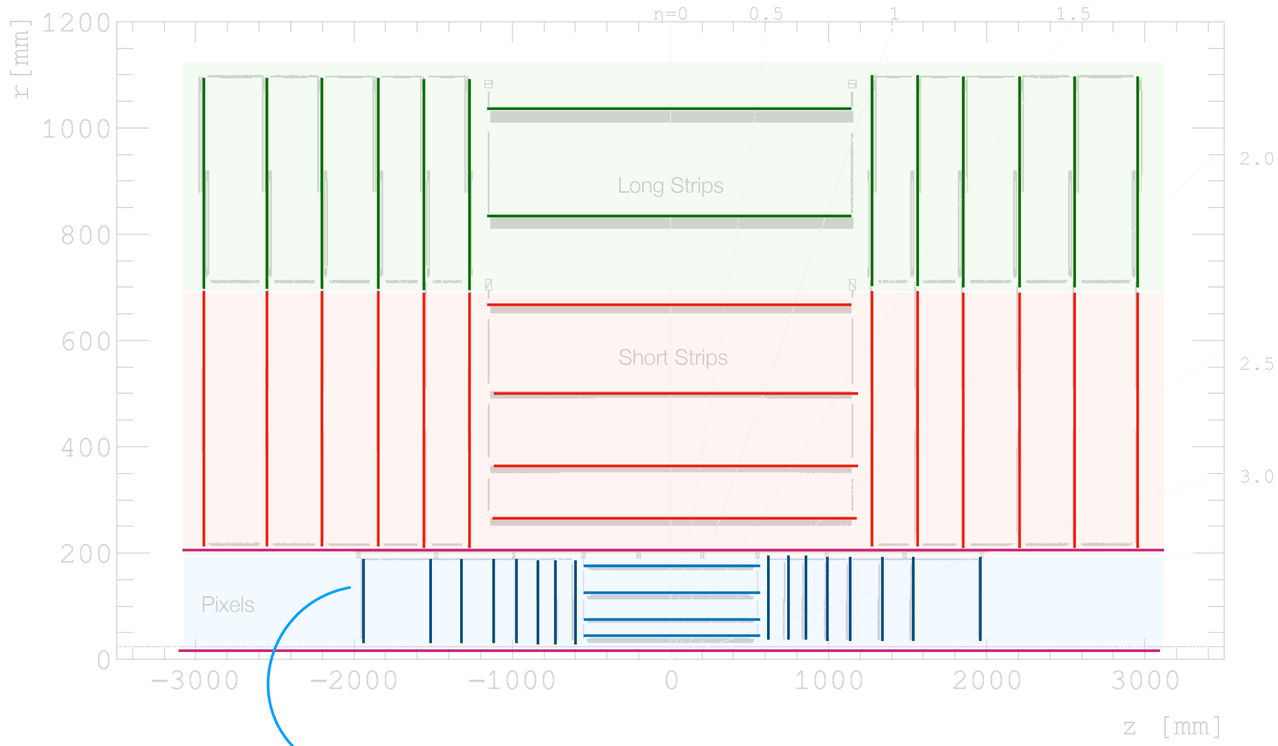
acts / Core / include / Acts

📁 Material

Experiment description: material

TOOLBOX

(2) Define a set of surfaces with some binning definition



Json configuration file that defines which surfaces to be used for material mapping (and map granularity)

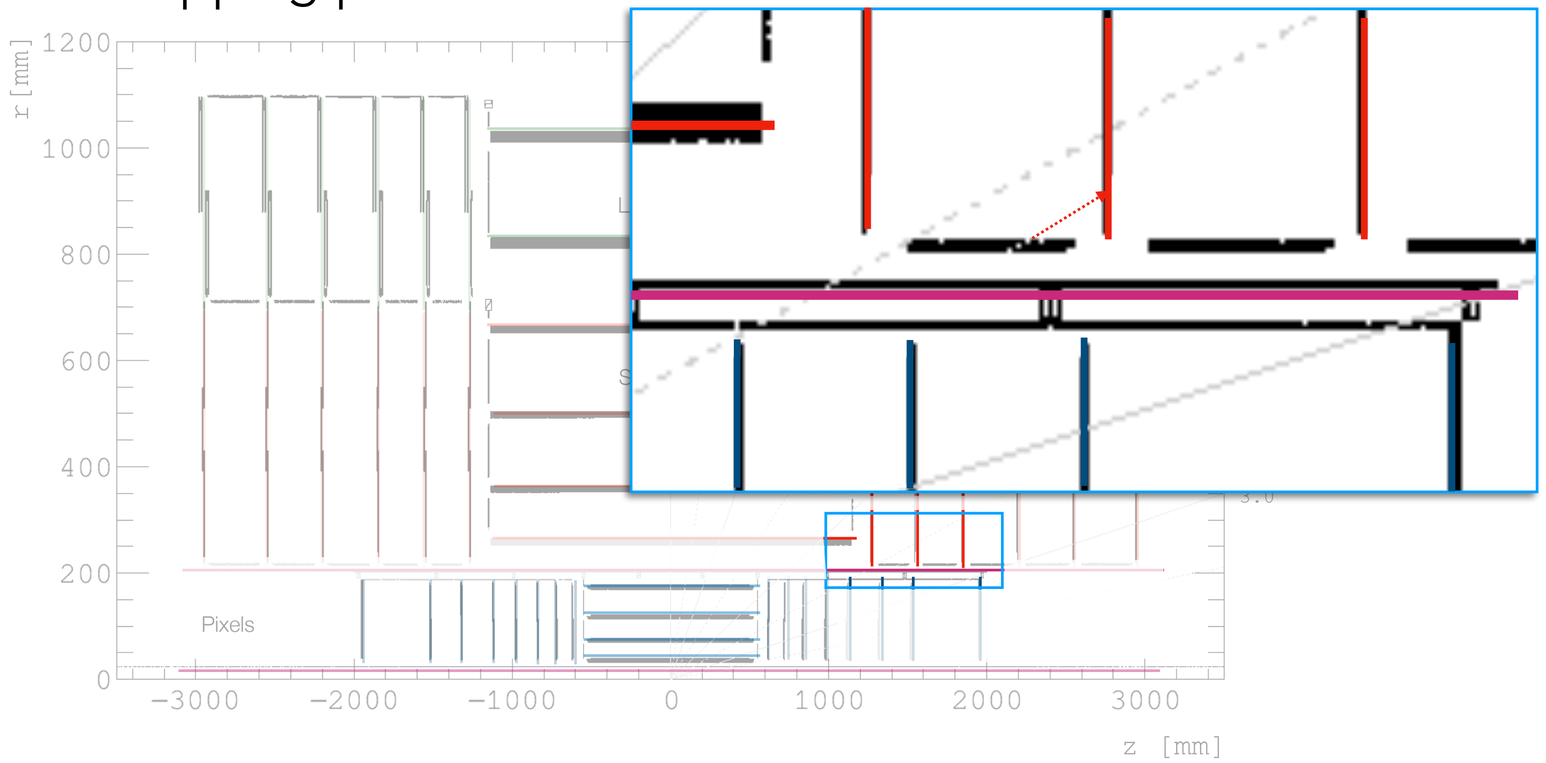
acts / Core / include / Acts

Material

Experiment description: material

TOOLBOX

(3) Run the mapping process

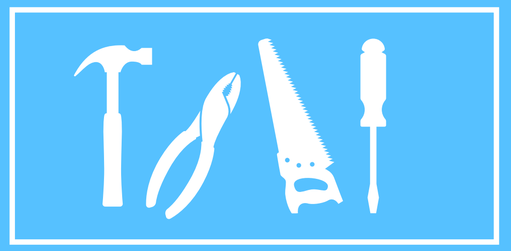


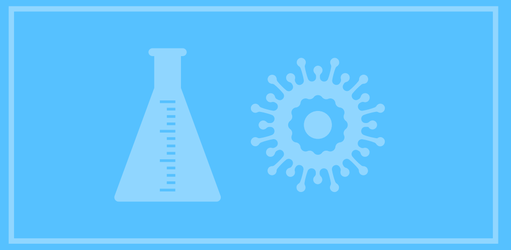
Geant4 material is projected onto next surface with eligible for mapping.

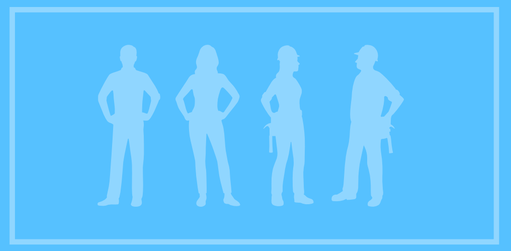
More work for volume based Material needed still.

acts / Core / include / Acts

Material

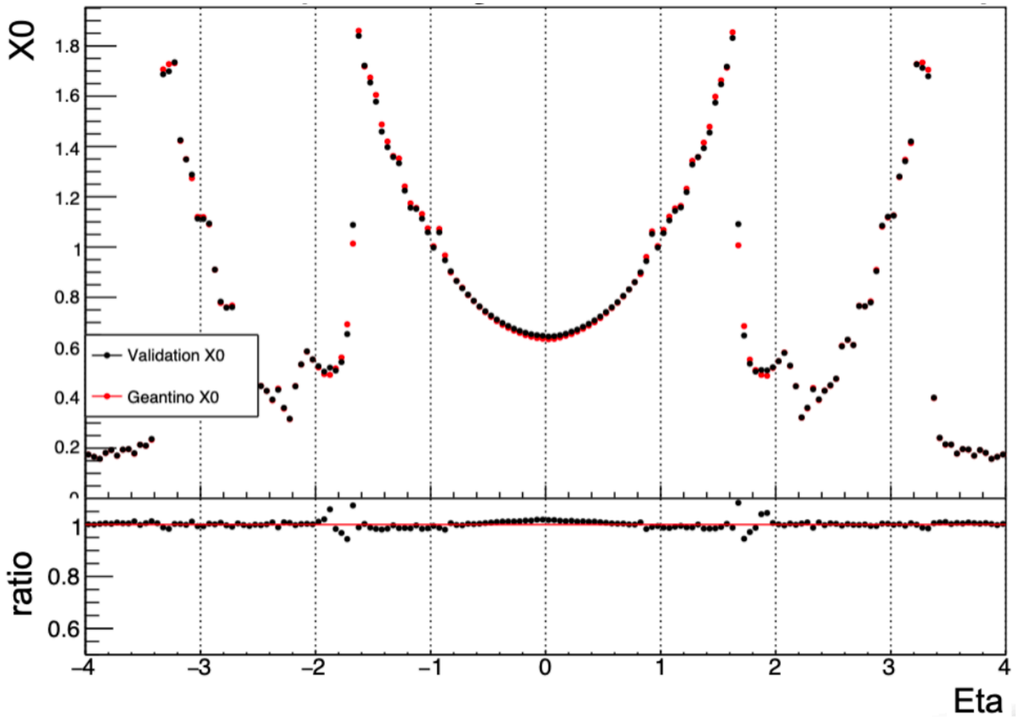






Experiment description: material

(3) Validate

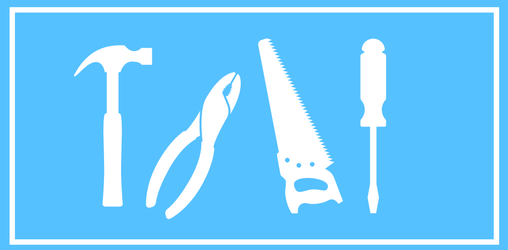


These outputs are available for you from ACTS directly

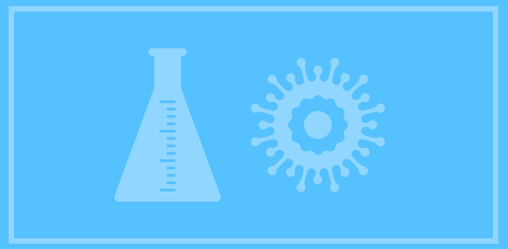
Ongoing work to decouple that from the framework.

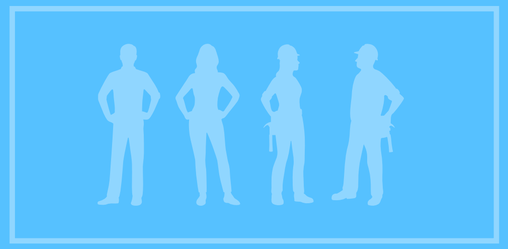
acts / Core / include / Acts

Material



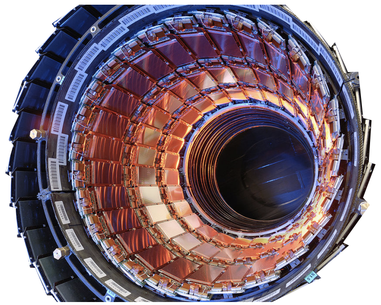
TOOLBOX



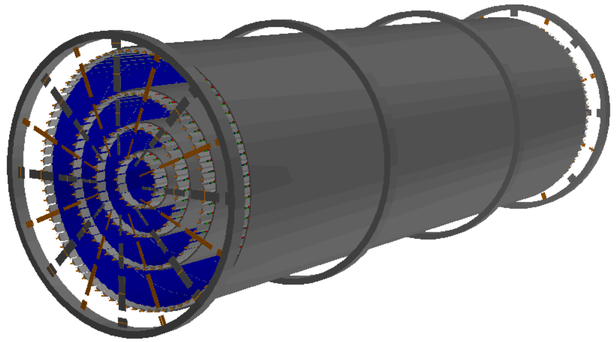


Experiment description: alignment

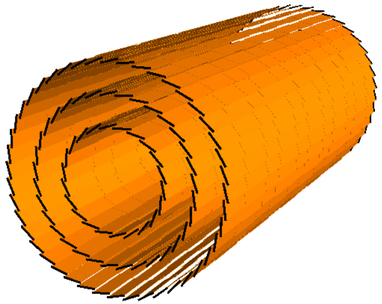
Reality



Full simulation



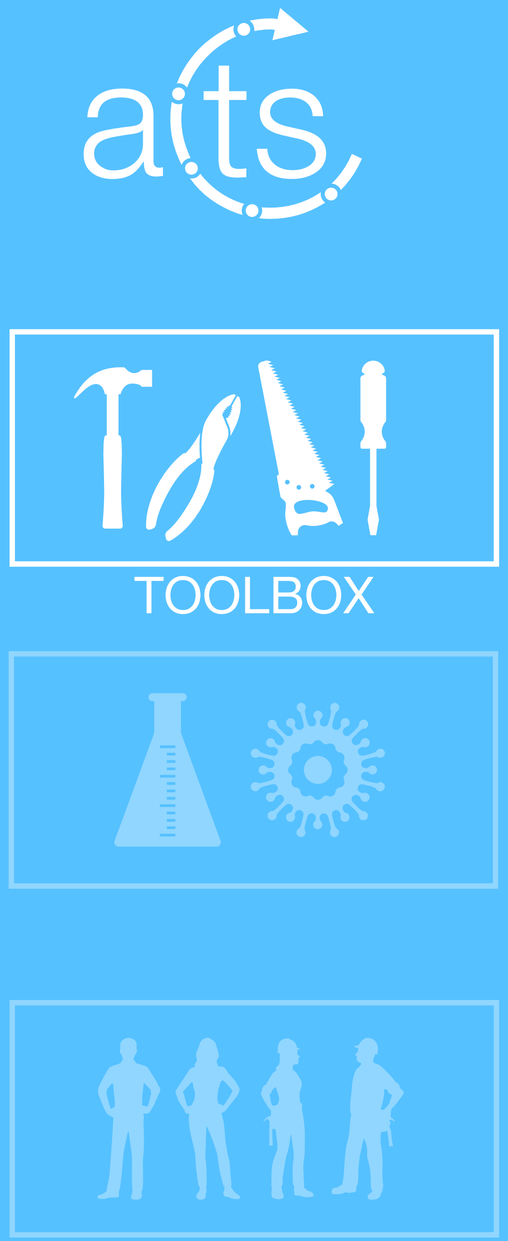
Reconstruction



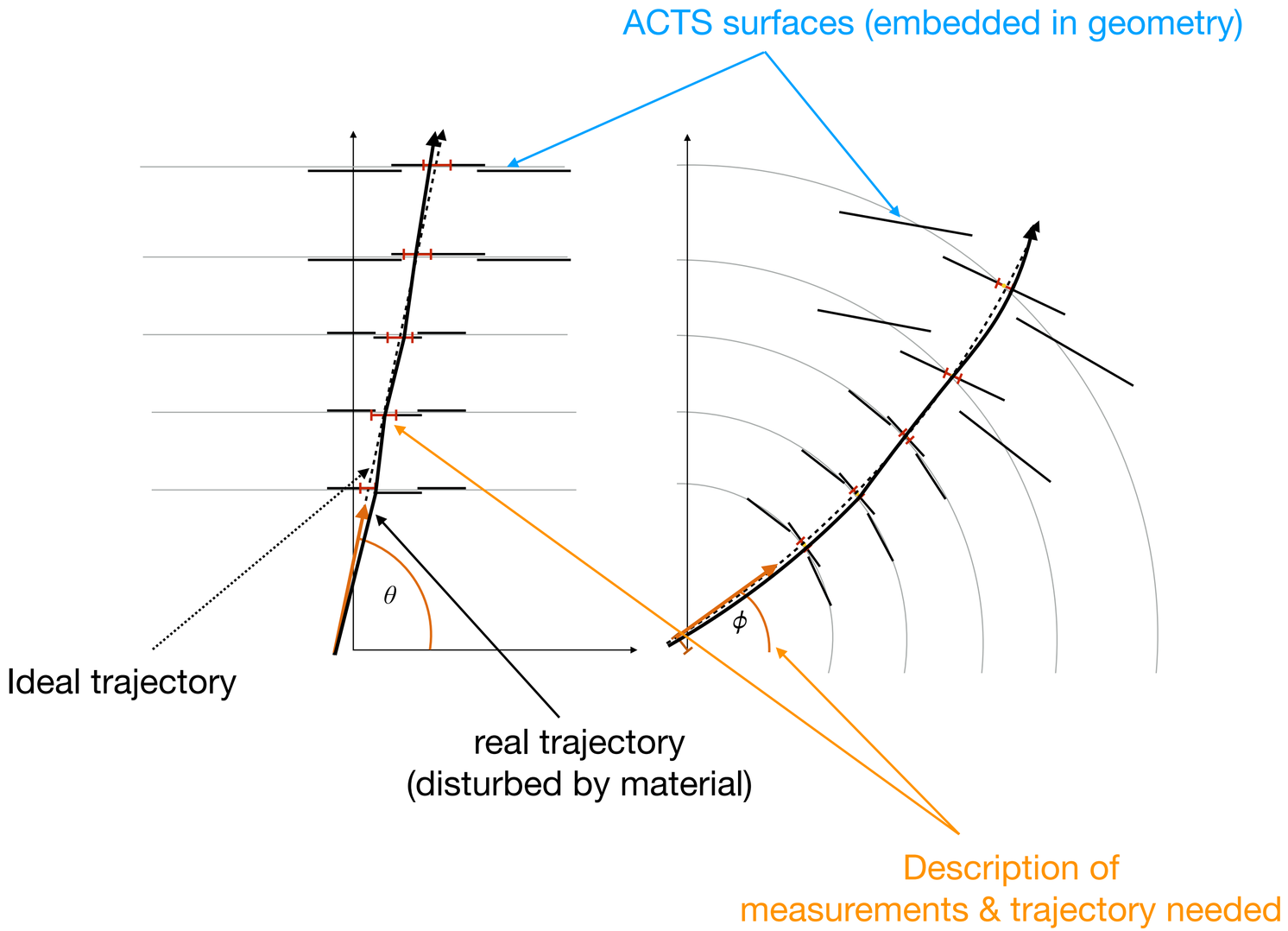
Detectors in real life are usually misaligned, need a mechanism to allow for event-wise misalignment.

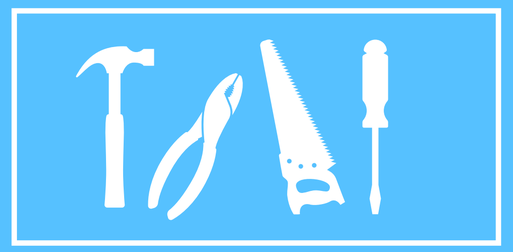
Built-in parallel processing enhanced alignment

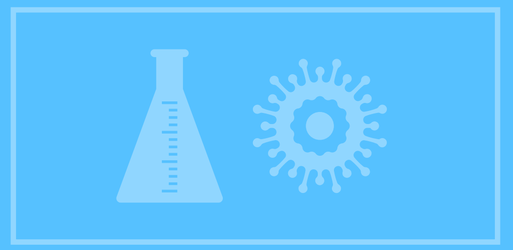
```
namespace Acts {
  class Module {
    /// @param gctx the geometry context (e.g. alignment)
    /// @param input the input data
    OutputData geometricOperation(const GeometryContext& gctx,
                                  const InputData& input) const;

  };
}
```

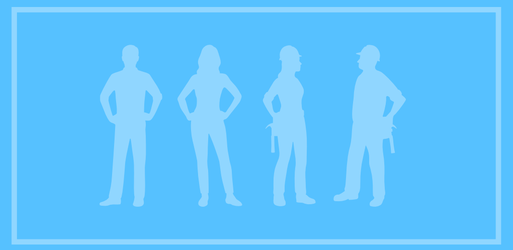


A particle through the detector





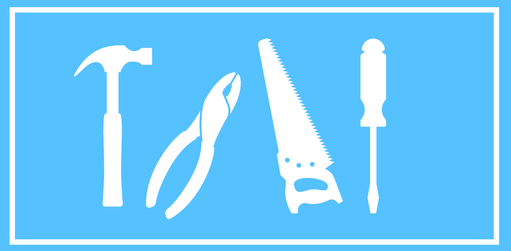


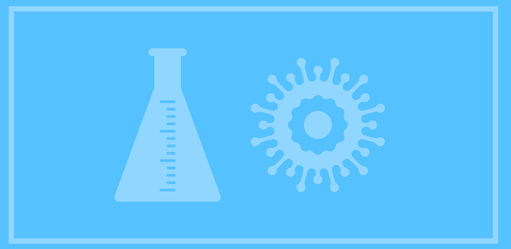


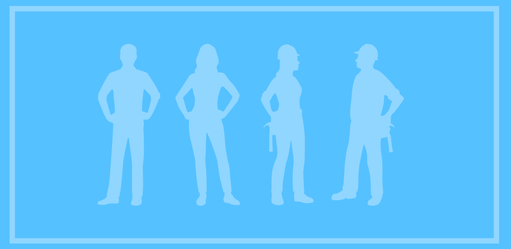
What is in the toolbox?

Geometry & Material

Event Data Model

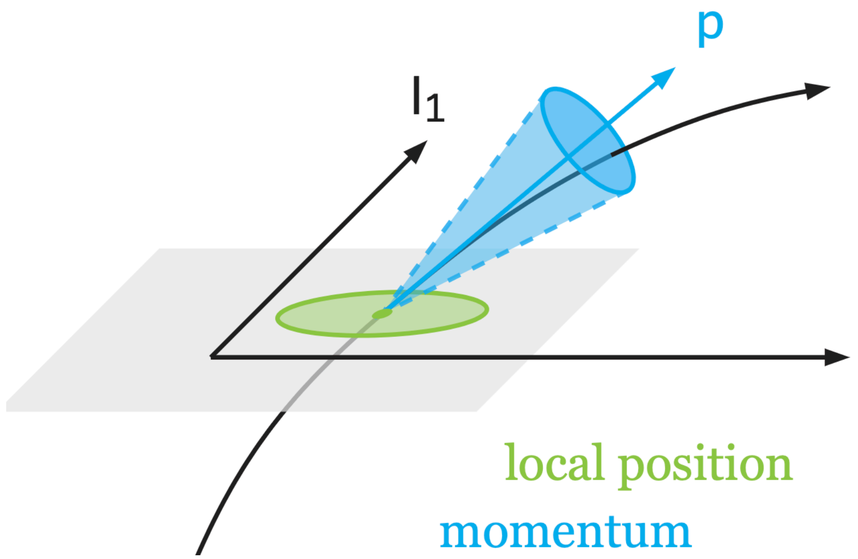


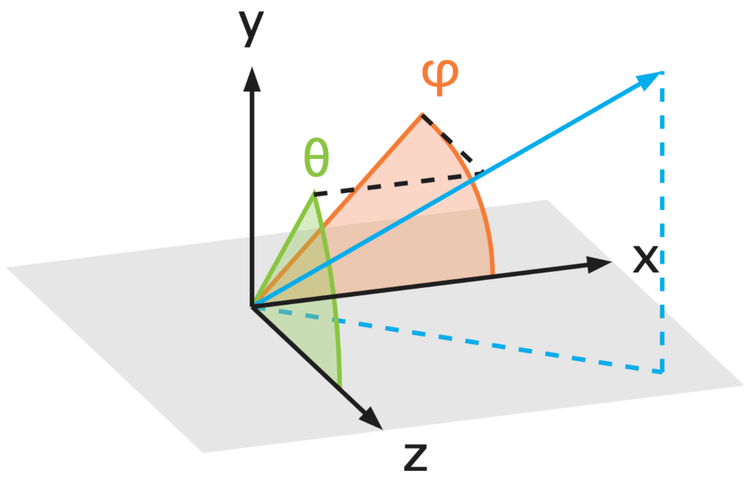




Data description

(1) Track parameters

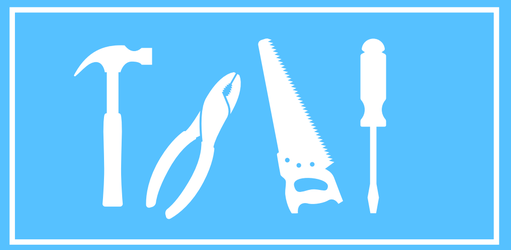


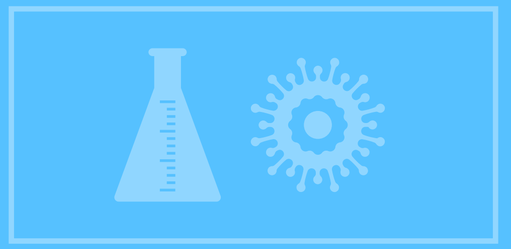


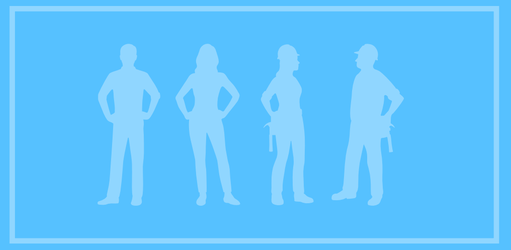
$$\vec{x} = (l_0, l_1, \phi, \theta, q/p, t)^T$$

acts / Core / include / Acts

EventData

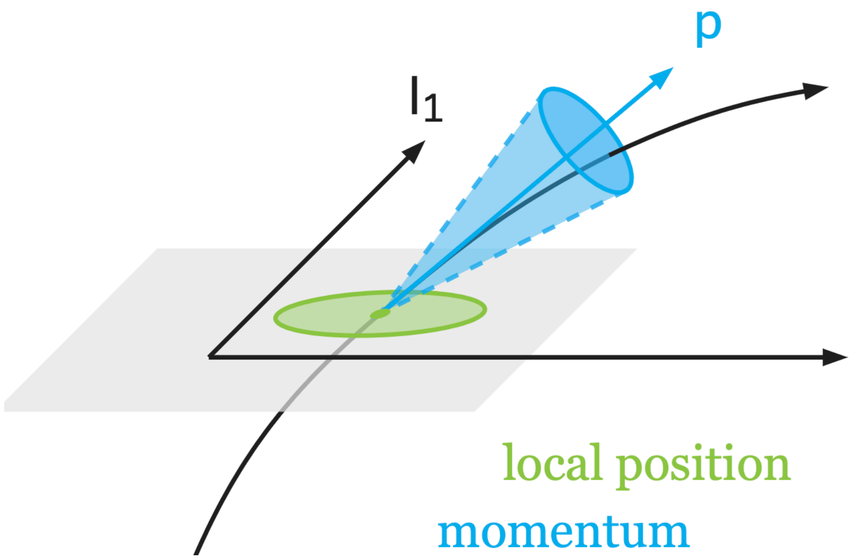


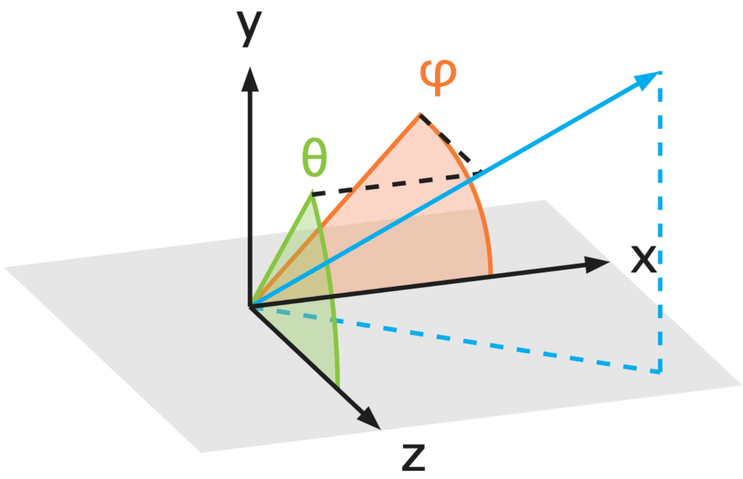




Data description

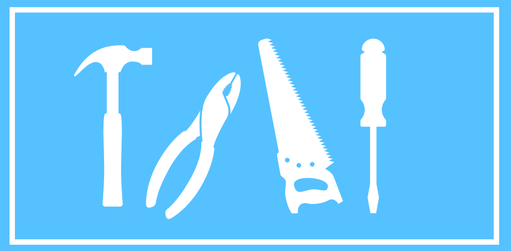
(1) Track parameters



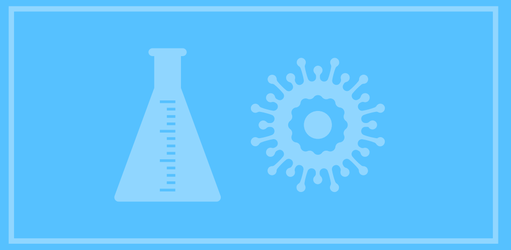


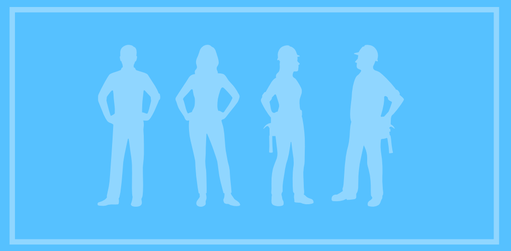
This is not necessarily the optimal choice for telescope like detectors where traditionally the detection planes are often described along the global z axis.

Some experiments, like LDMX have thus rotated the reconstruction frame towards positioning along x.



TOOLBOX





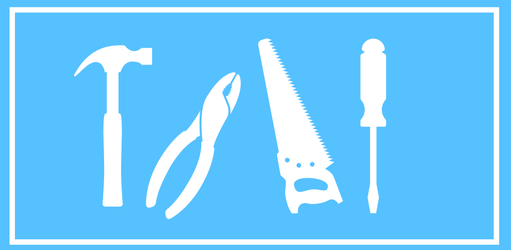
Data description

(2) Measurements

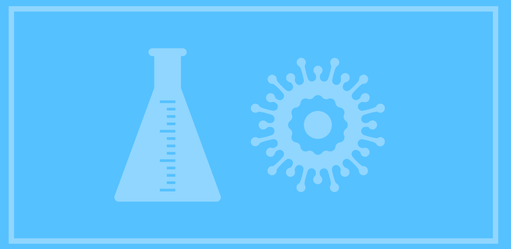
Parameter	l_0	l_1	ϕ	θ	q/p	t
Bound track parameters						
Pixel measurement						
Pixel measurement with time						
Strip measurement (along local x)						
Strip measurement (along local y)						
Drift time/circle measurement						
Track segment (straight line)						
…						

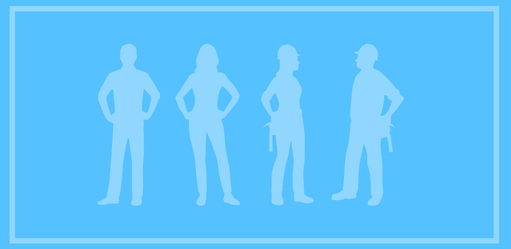
acts / Core / include / Acts

📁 EventData



TOOLBOX

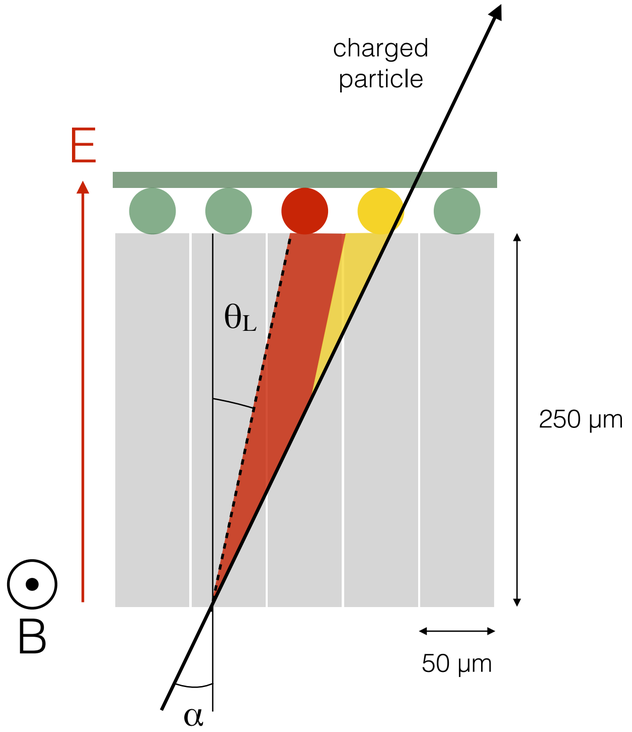




Data description

(2) Measurements

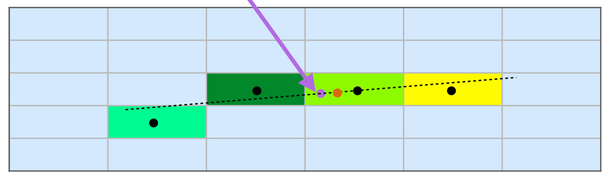
E.g. planar measurements



the charge-weighted approach :

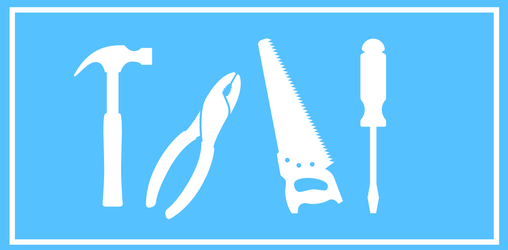
$$\mathbf{m} = \frac{1}{\sum_{i=1,N} q_i} \sum_{i=1,N} q_i l_i$$

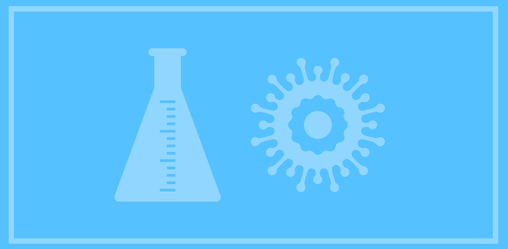
charge collected in cell i

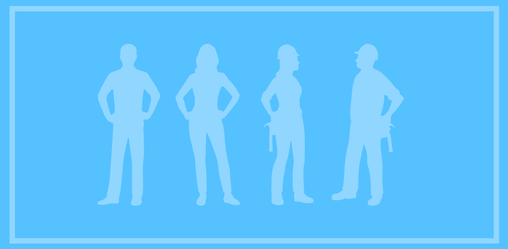


acts / Core / include / Acts

EventData



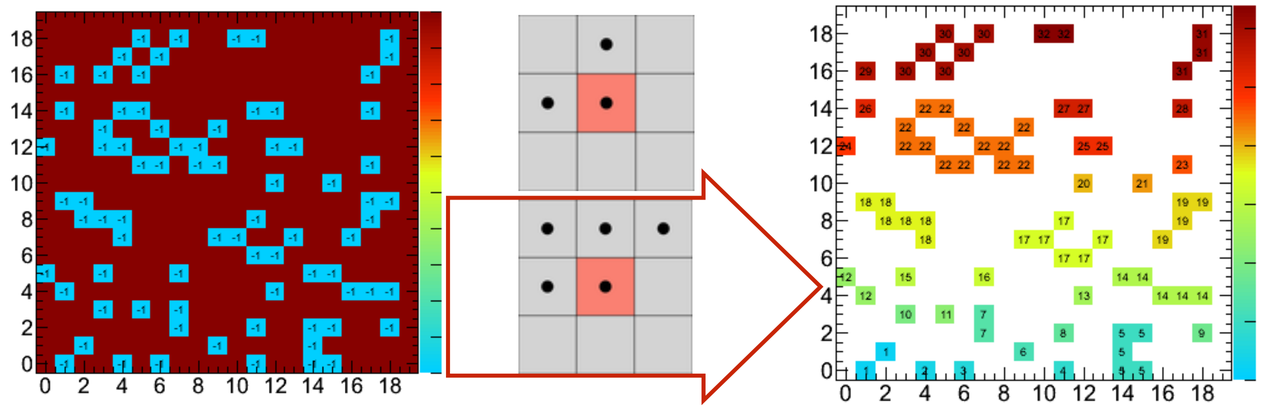




Data description

(2) Measurements

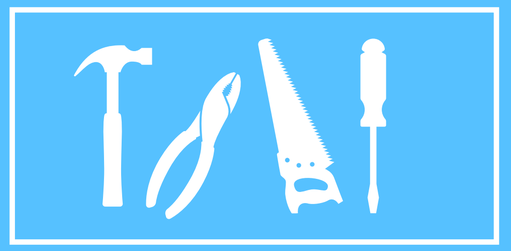
Creation from single cells using connected component labelling

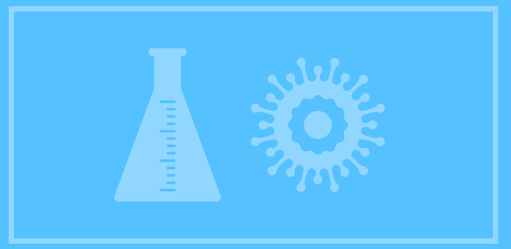


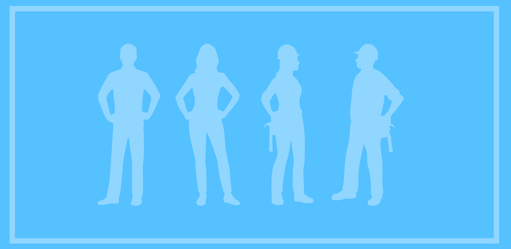
4- and 8-cell connectivity supported

acts / Core / include / Acts

📁 Clusterization



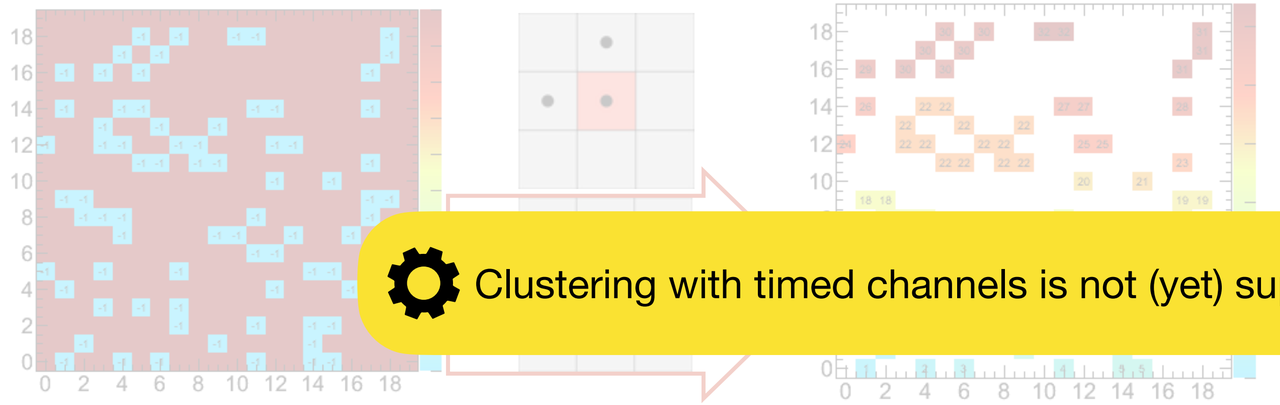




Data description

(2) Measurements

Creation from single cells using connected component labelling

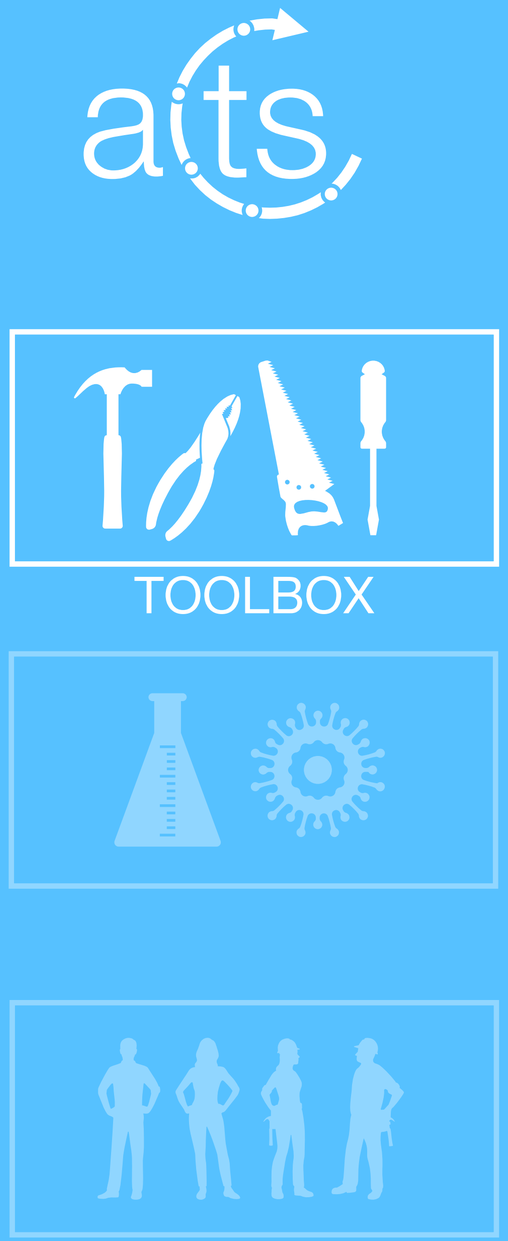


Clustering with timed channels is not (yet) supported.

4- and 8-cell connectivity supported

acts / Core / include / Acts

📁 Clusterization



Data description

(2) Measurements

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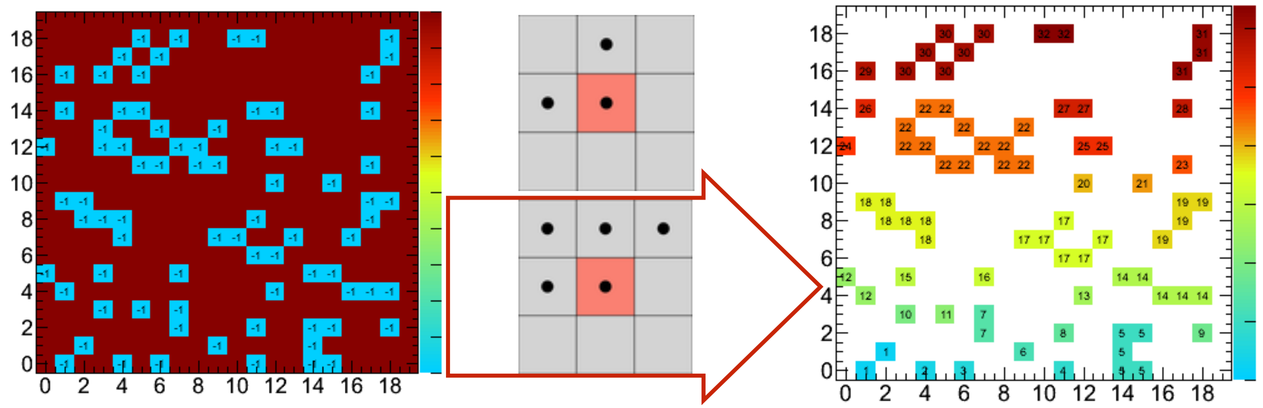
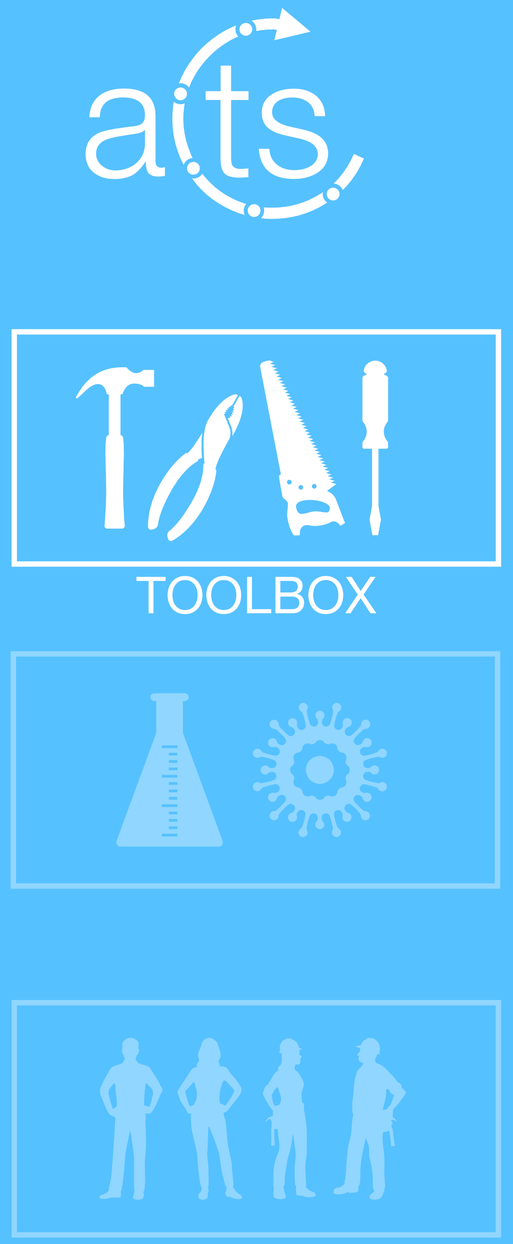


4- and 8-cell connectivity supported

Connected component labelling is a deterministic problem and has one exact answer.

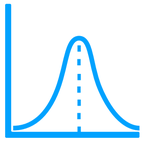
Different implementations, however, differ a lot in speed and parallel execution capabilities.



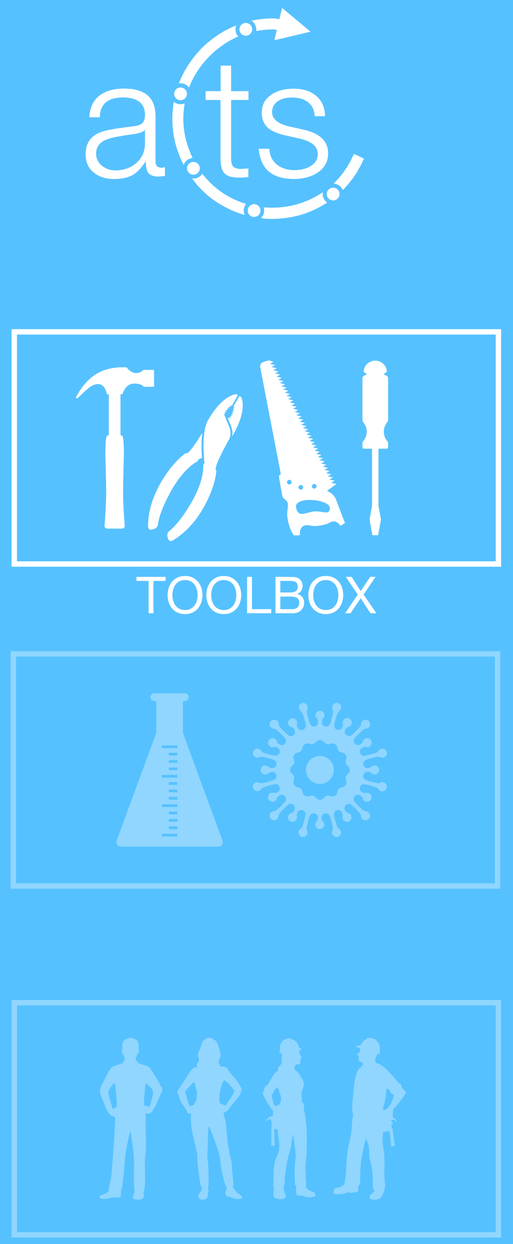
What is in the toolbox?

Geometry & Material

Event Data Model

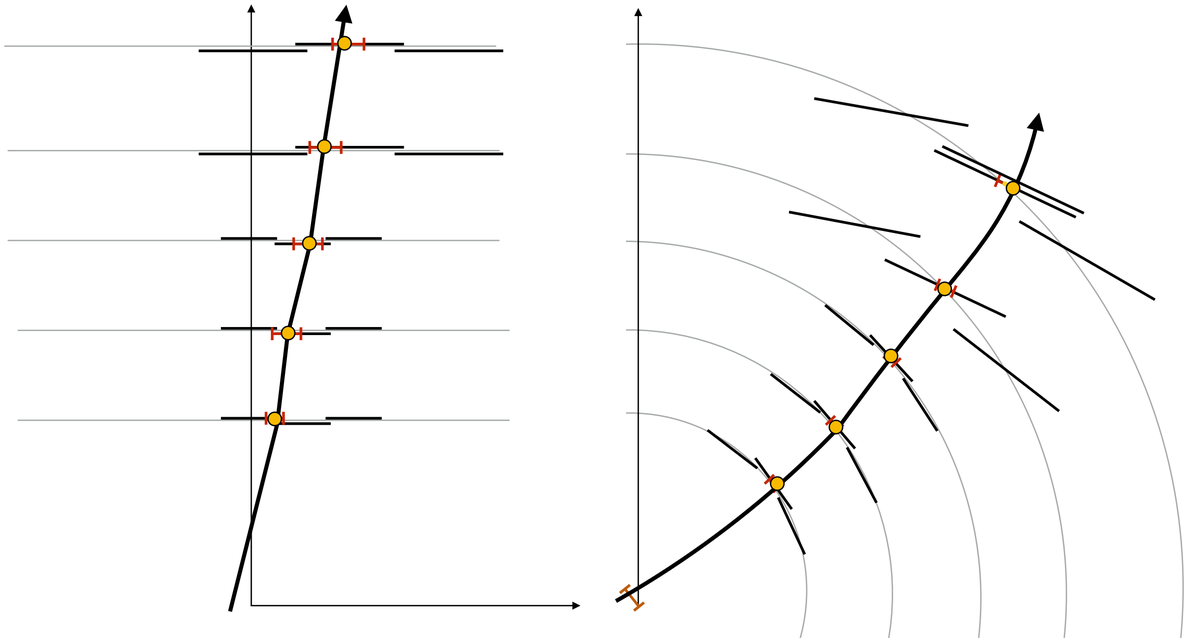


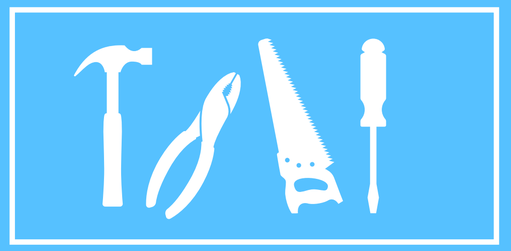
Track Finding & Fitters

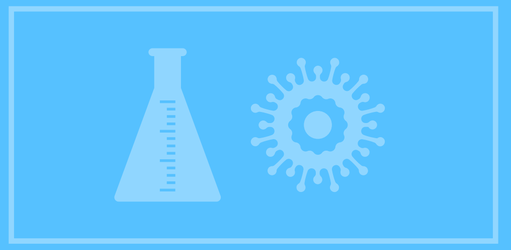


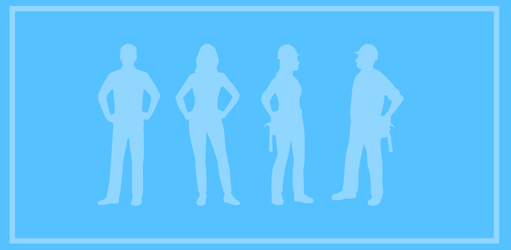
Space points

Next step: expression of those measurements as 3D points









Space points

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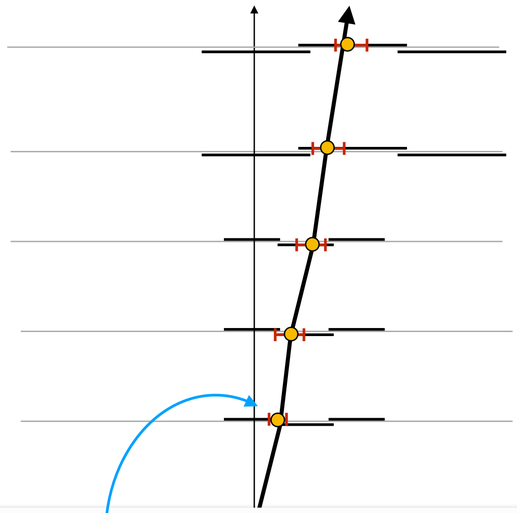
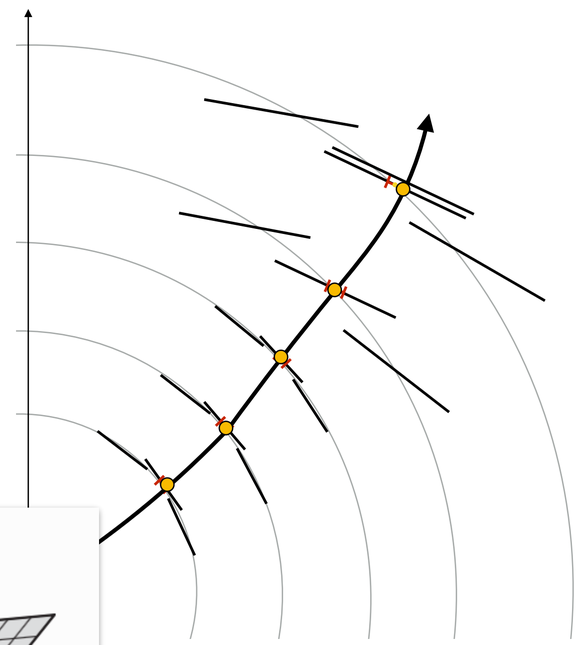
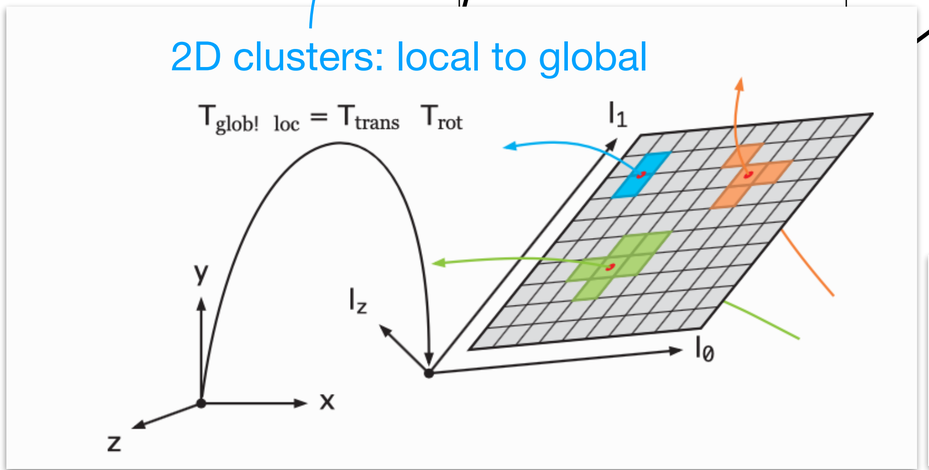




2D clusters: local to global



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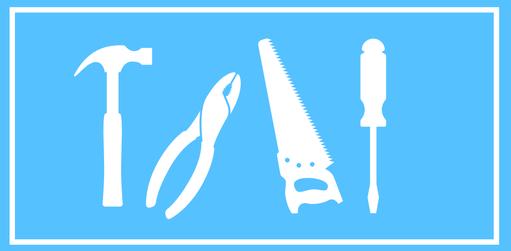
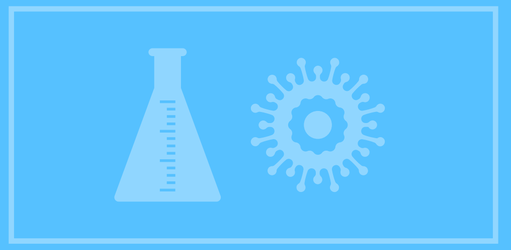
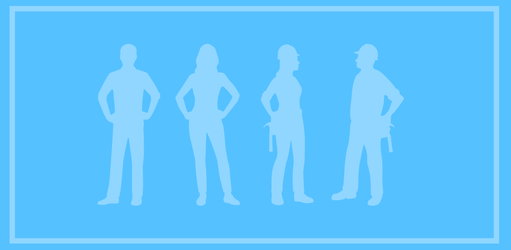
SpacePointFormation







Space points

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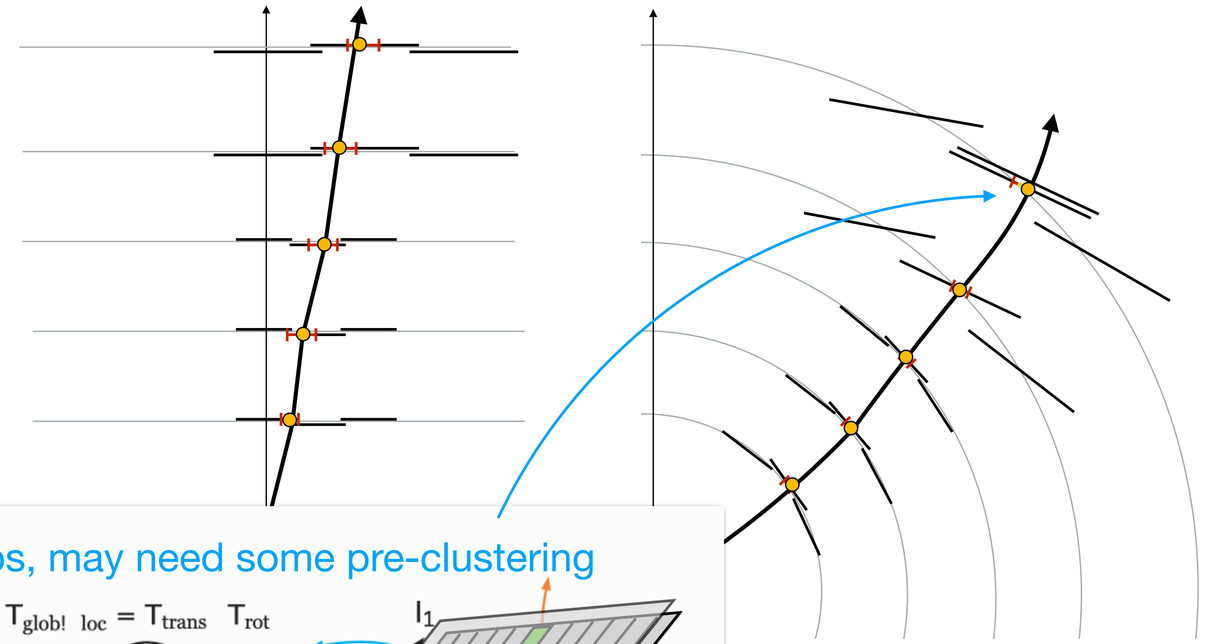
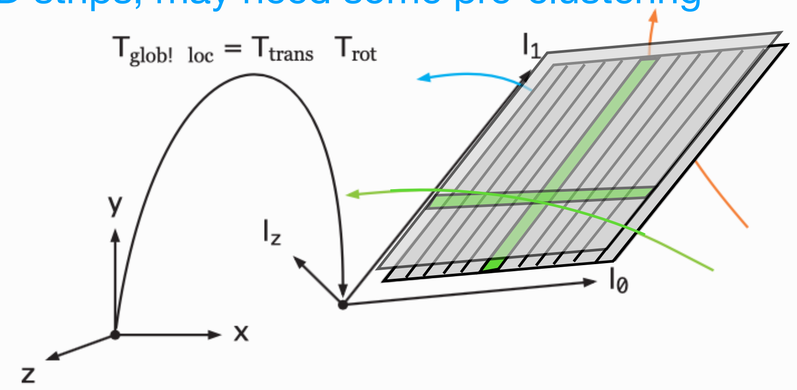
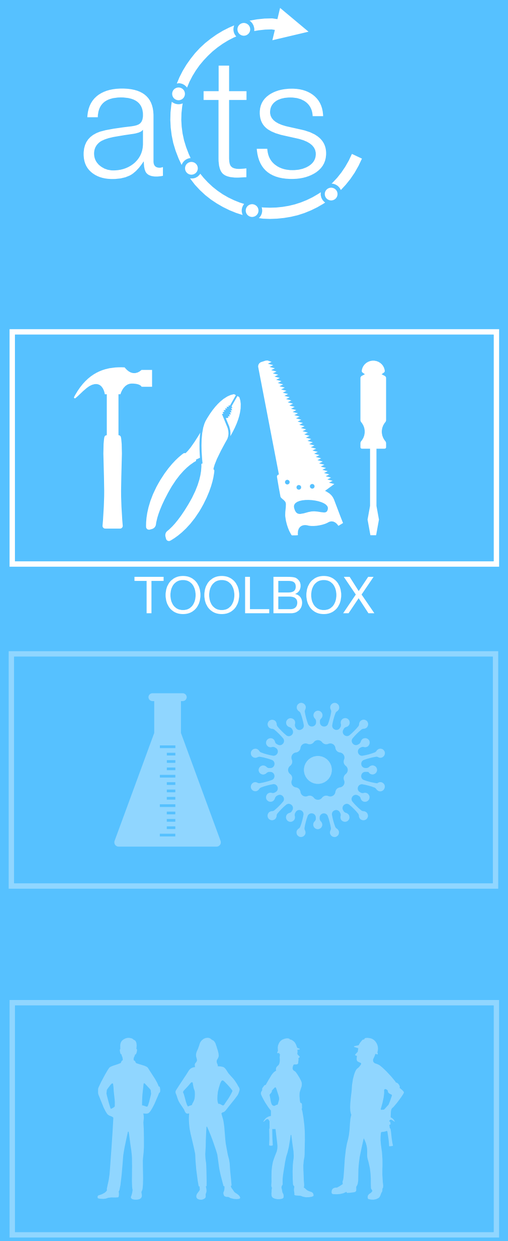


1D strips, may need some pre-clustering

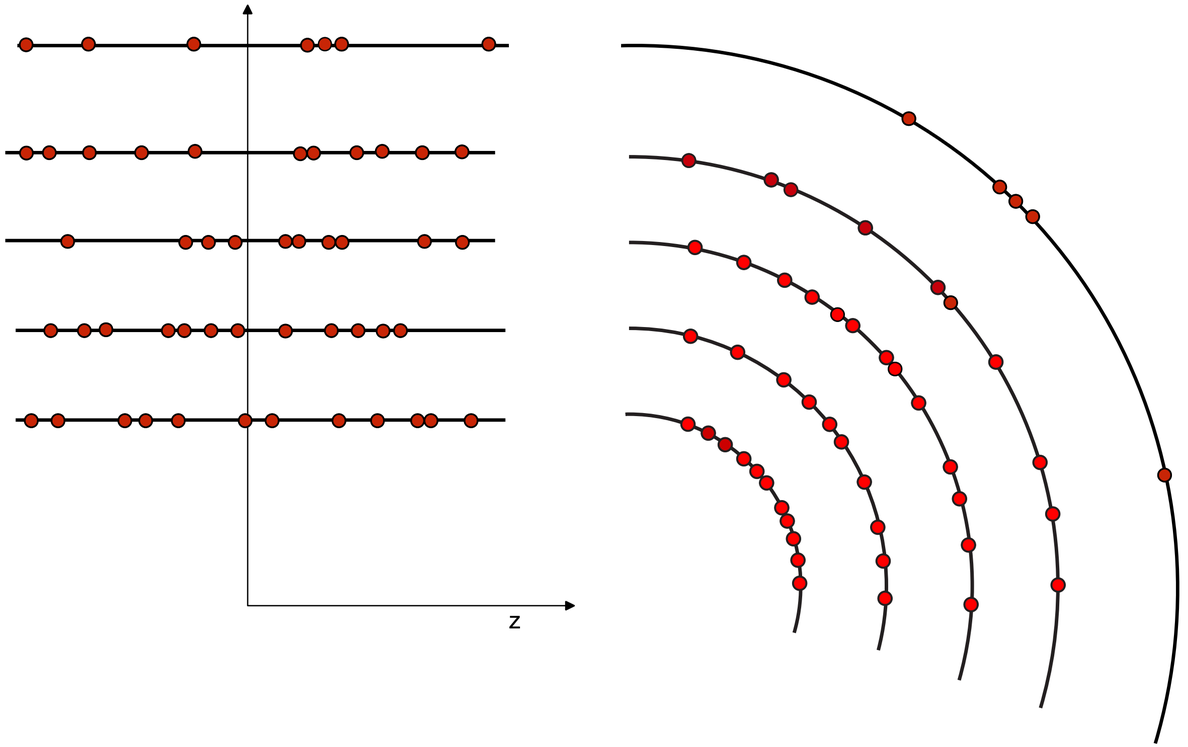


acts / Core / include / Acts

SpacePointFormation

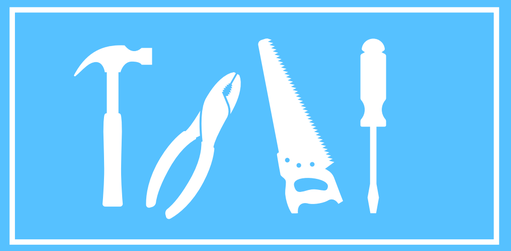


Seeding

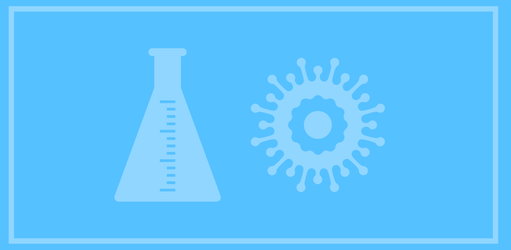


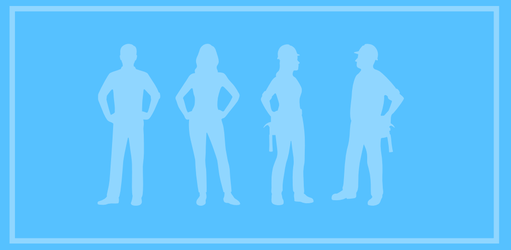
acts / Core / include / Acts

📁 Seeding



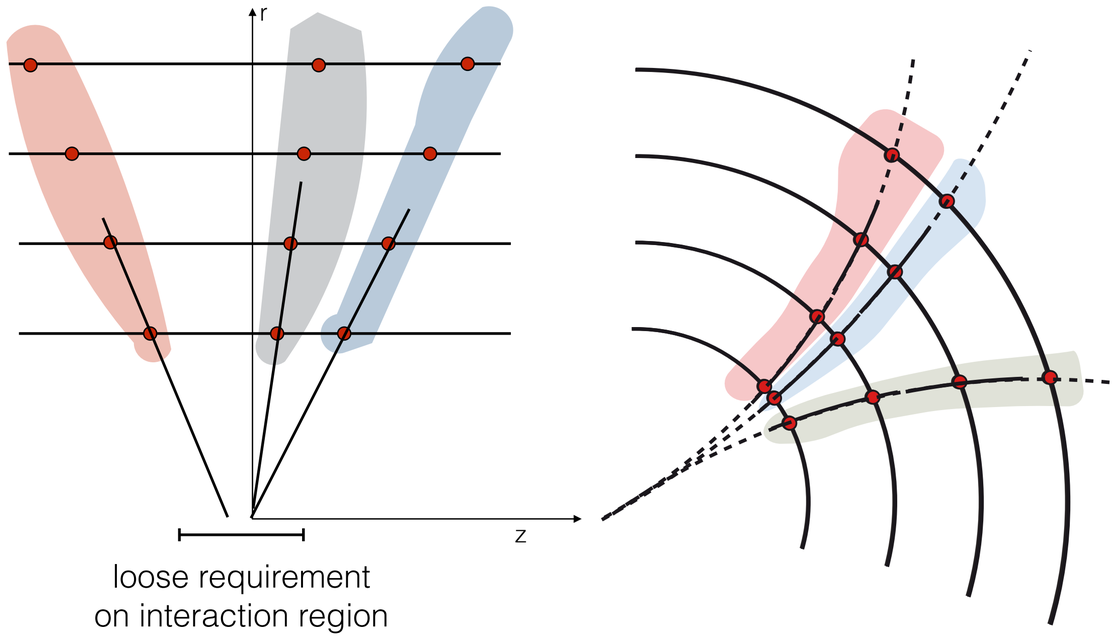
TOOLBOX





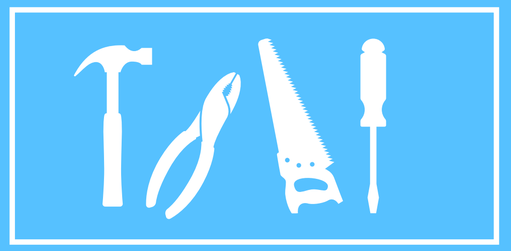
Seeding

Find doublets and successively trips of hits compatible with crude track candidate.

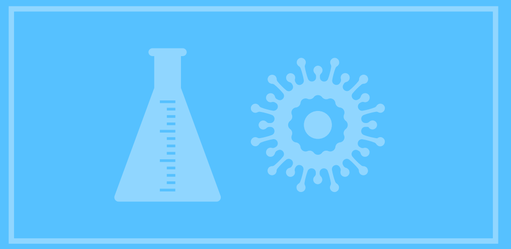


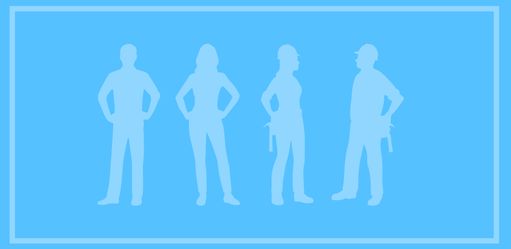
acts / Core / include / Acts

📁 Seeding



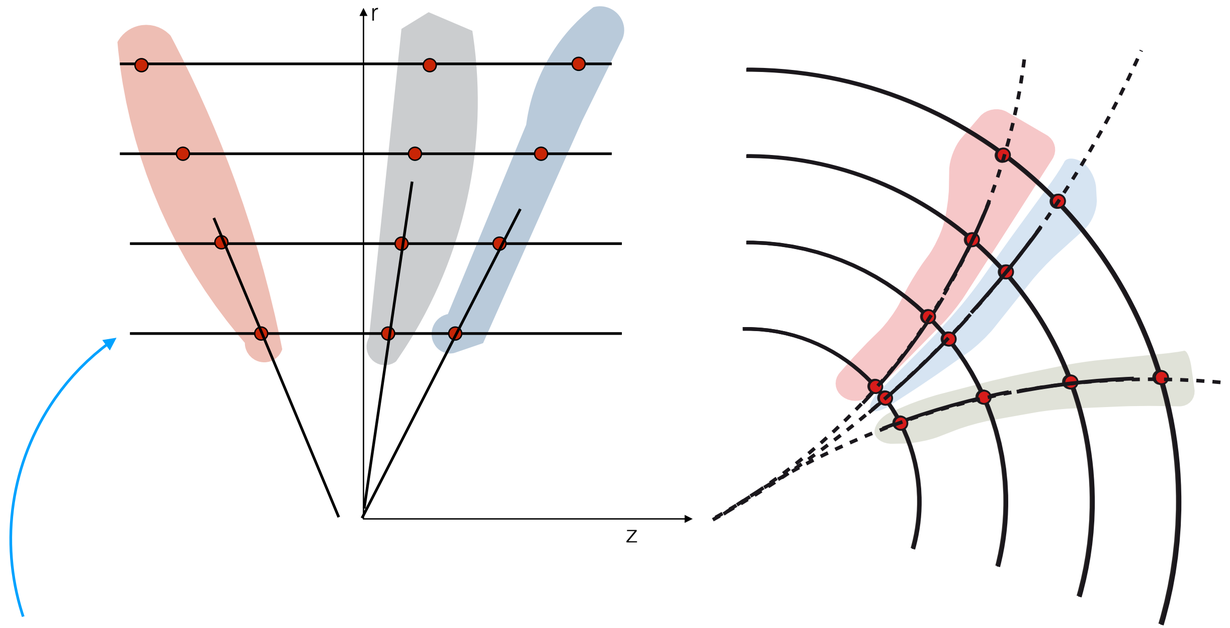
TOOLBOX





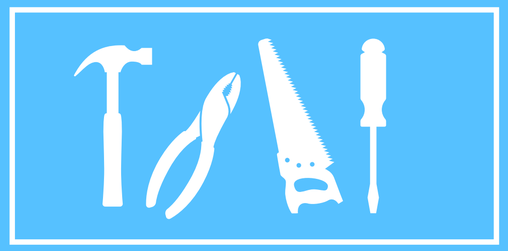
Seeding

Find doublets and successively trips of hits compatible with crude track candidate.

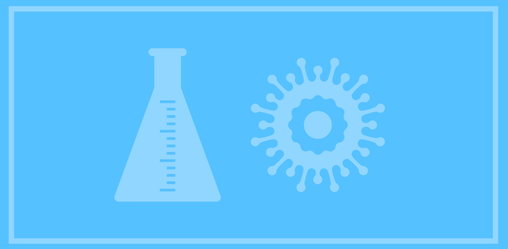


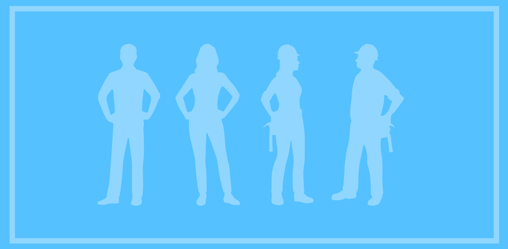
Layers that are permitted for seeding can be configured in ACTS with a seeding struct, and associated json file API.

This simple example has already 12 correct seeds for 3 particles; seeding is the firs part of combinatorial explosion of the track finding problem.



TOOLBOX



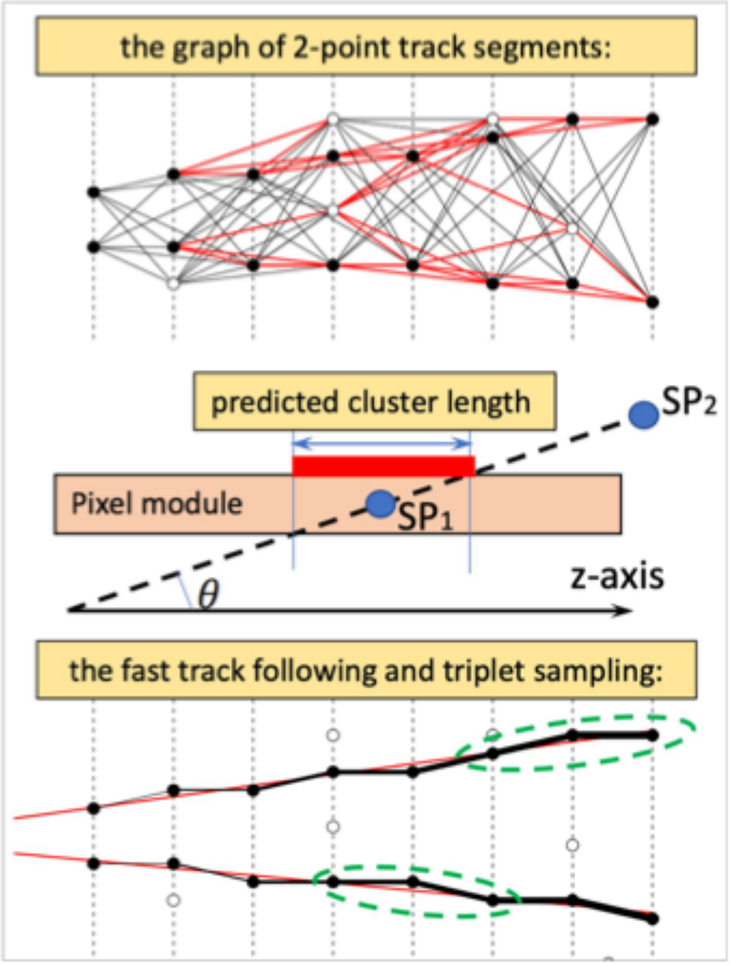


Alternative seeders

[link to talk]

Graph based seeders are becoming more & more popular as they tend to produce longer seeds (and thus suppress the combinators):

- GBTS (Graph Based Track Seeder)
- GNN (Graph Neural Network), see later



ACTS also deployed additional seeders:

- Orthogonal Seeder
- Telescope Seeder

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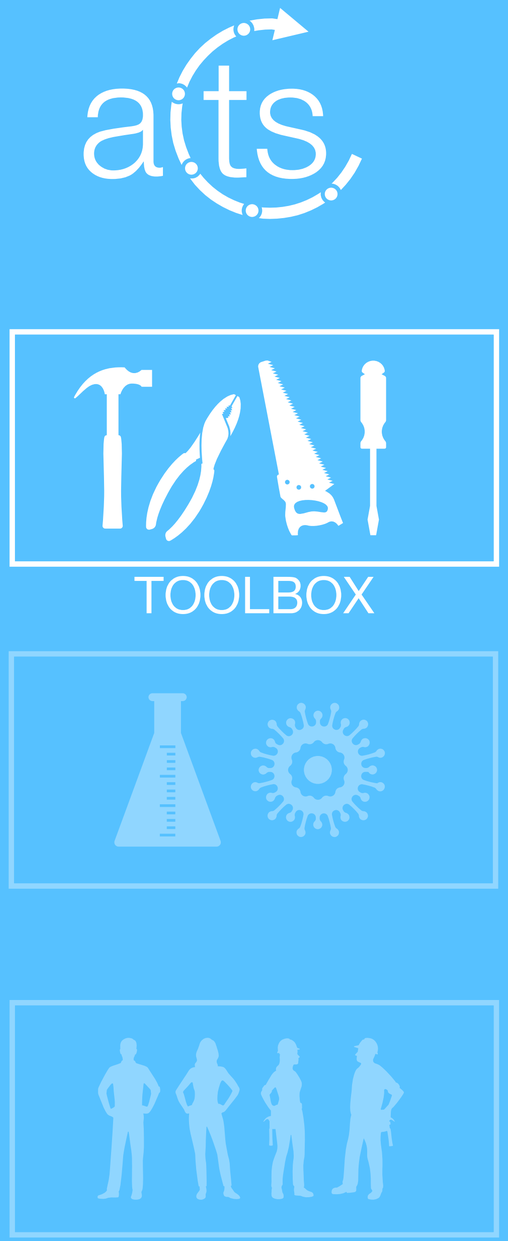
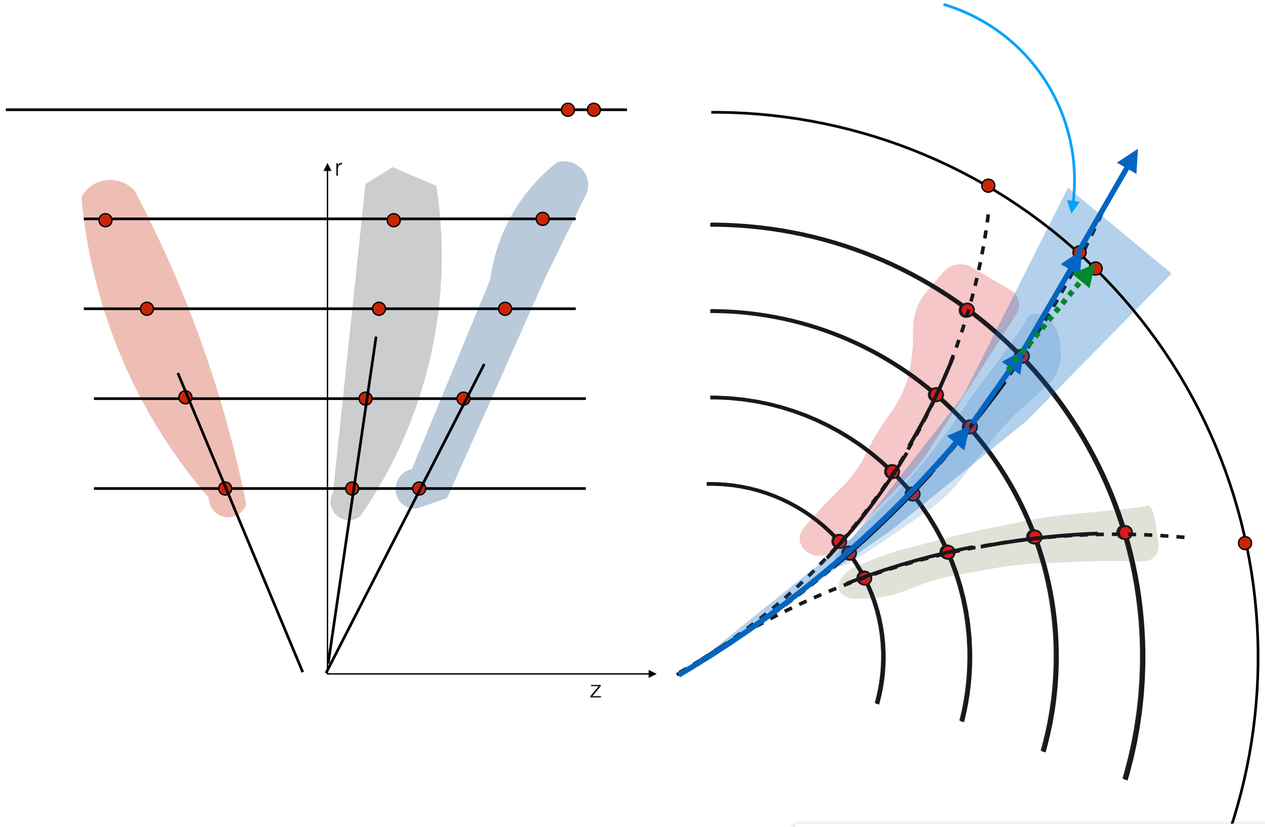
Seeding



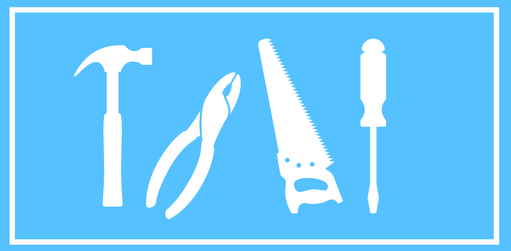
Track following

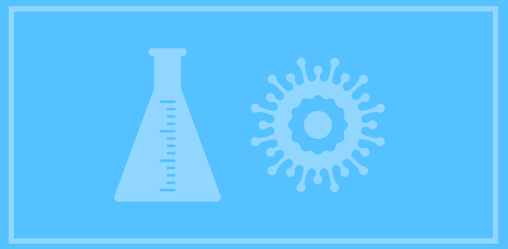
we need a filter to decide which one is a better candidate

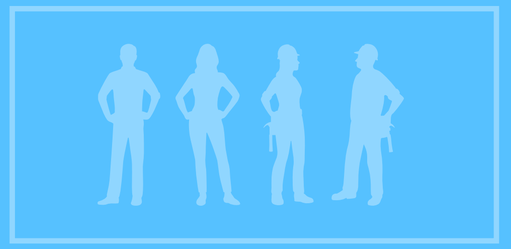


acts / Core / include / Acts

Fitting



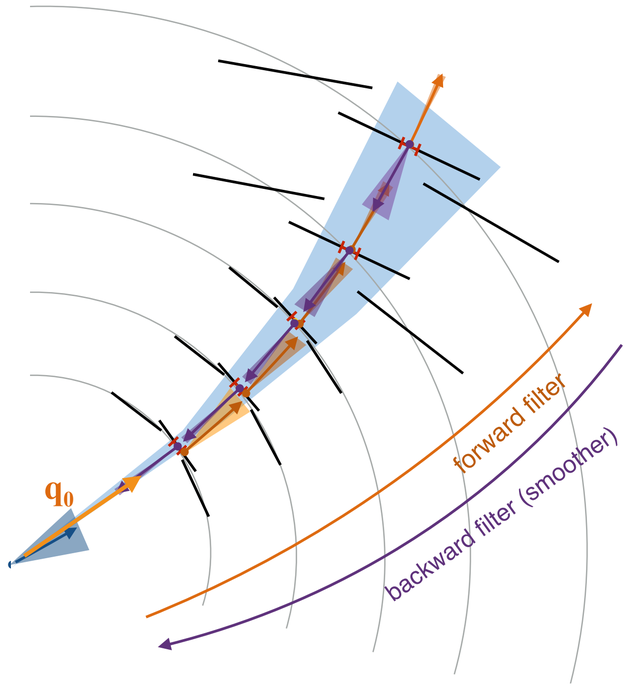




(Combinatorial) Kalman Filter

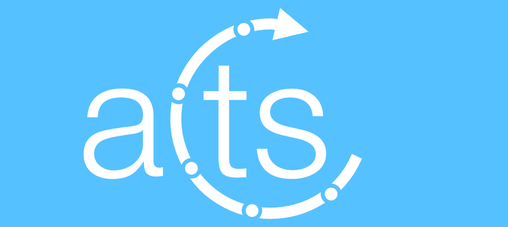
Default track finding strategy:

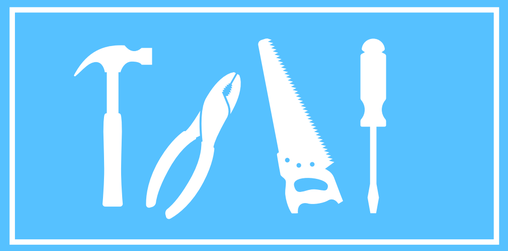
Using a Kalman Filter that is allowed to test different path hypothesis.



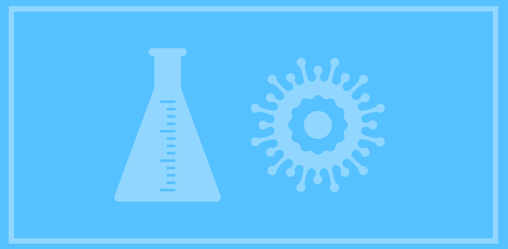
acts / Core / include / Acts

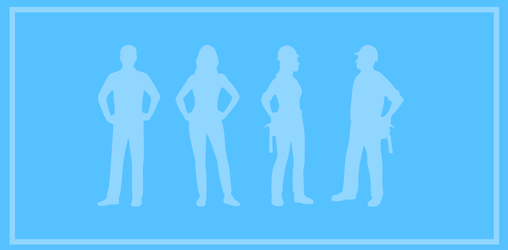
Fitting





TOOLBOX

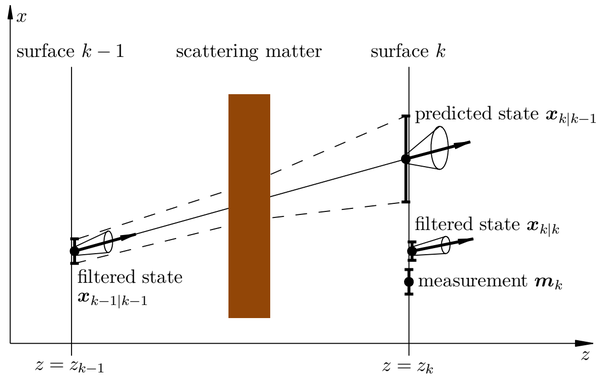


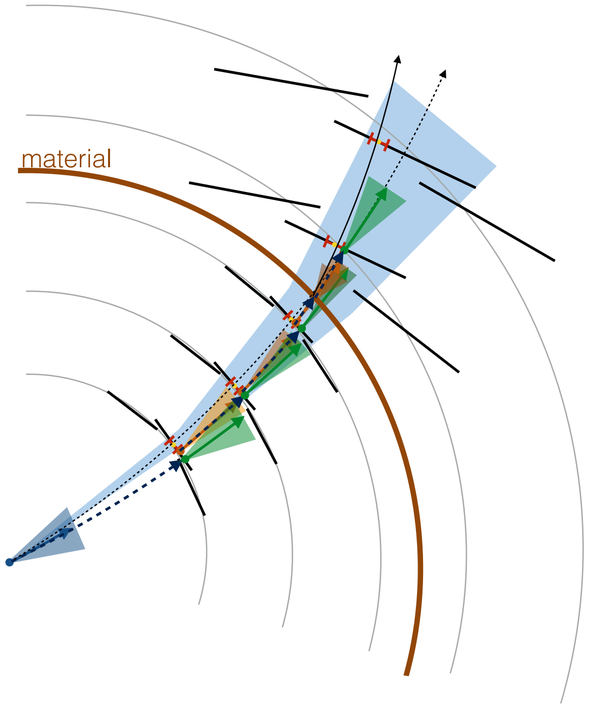


(Combinatorial) Kalman Filter

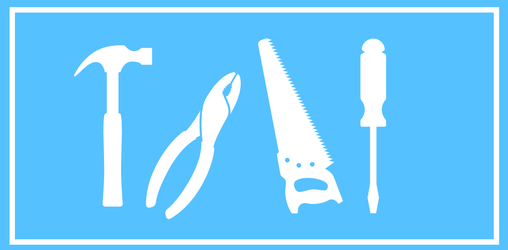
Default track finding strategy:

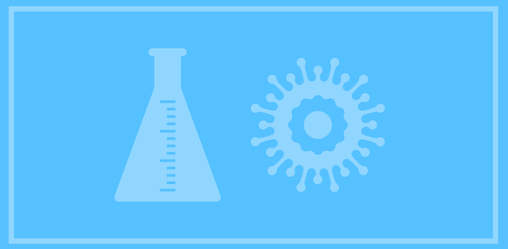
Using a Kalman Filter that is allowed to test different path hypothesis.

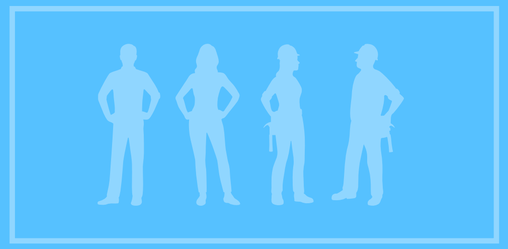




The correct fitting results relies on a good initial parameter estimate (usually from the seed) and a correct handling of the intrinsic error and material effects.







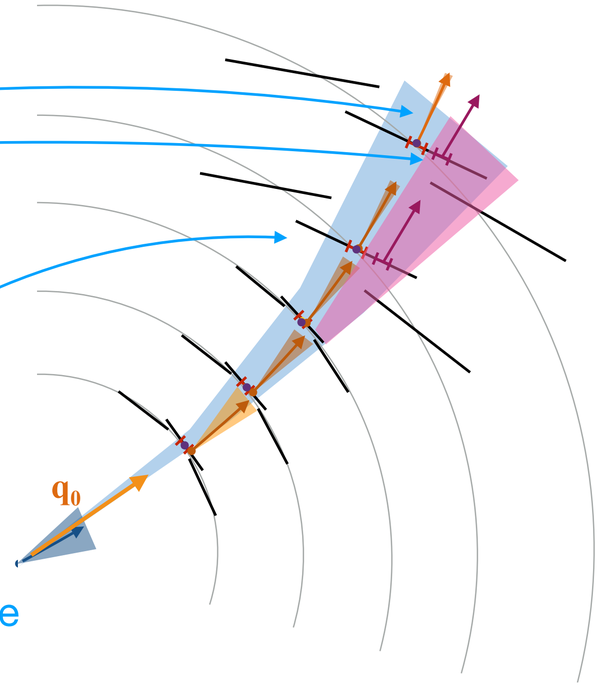
Combinatorial Kalman Filter

Default track finding strategy:

Using a Kalman Filter that is allowed to test different path hypothesis.

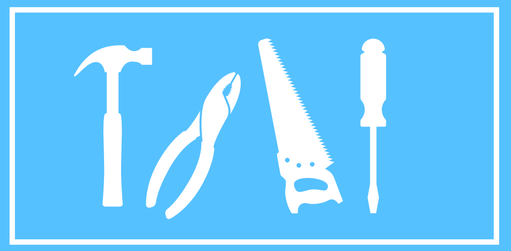
Track tips:
Concept of different possible end points of a trajectory are implemented in the ACTS MultiTrajectory track class.

Branching numer:
How many branches per surface are allowed can be configured.

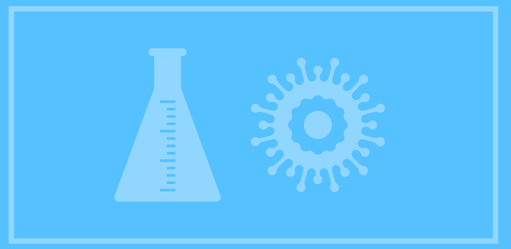


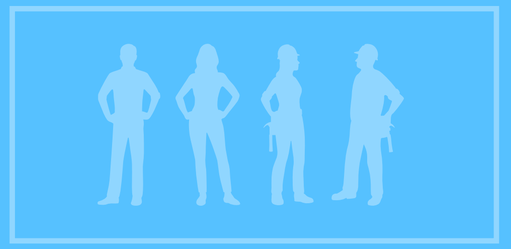
acts / Core / include / Acts

- EventData
- Fitting



TOOLBOX



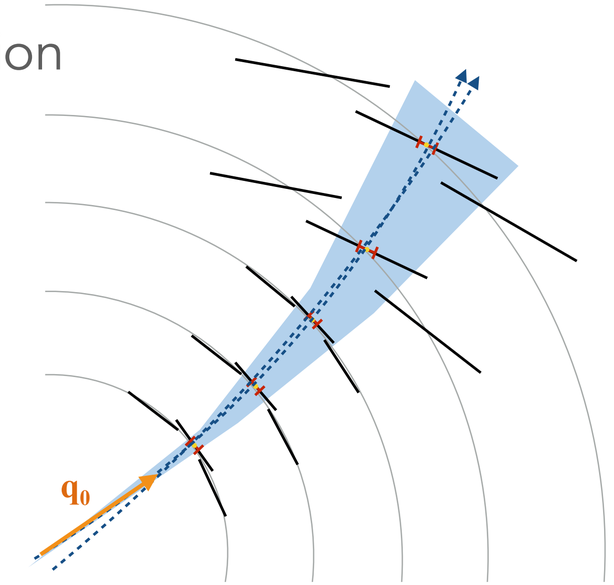


Pure track fitters: Global χ2 Fitter

Kalman filter is a linear progressive filter and can be locally unstable.

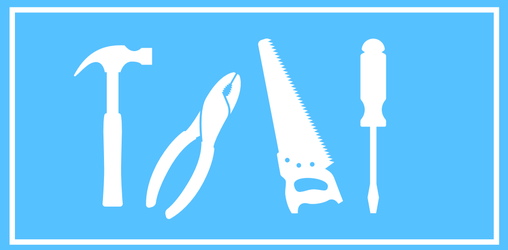
Alternatively, a global minimalisation fitter is also available.

Usually more stable in ambiguous measurement regimes, e.g. signed drift circles.

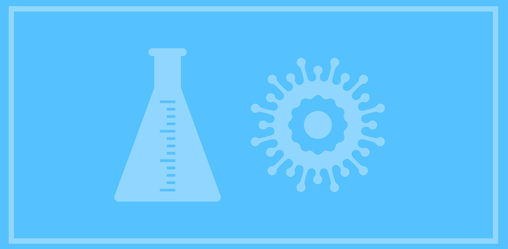


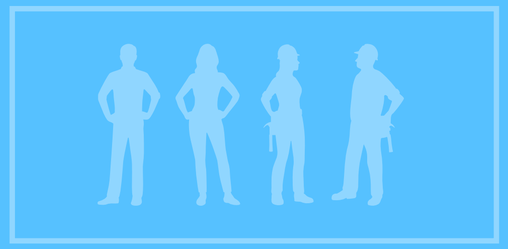
acts / Core / include / Acts

📁 Fitting



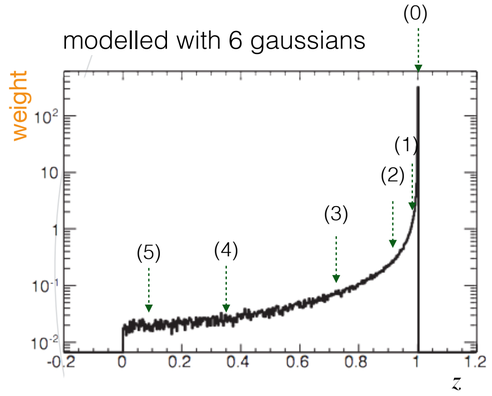
TOOLBOX

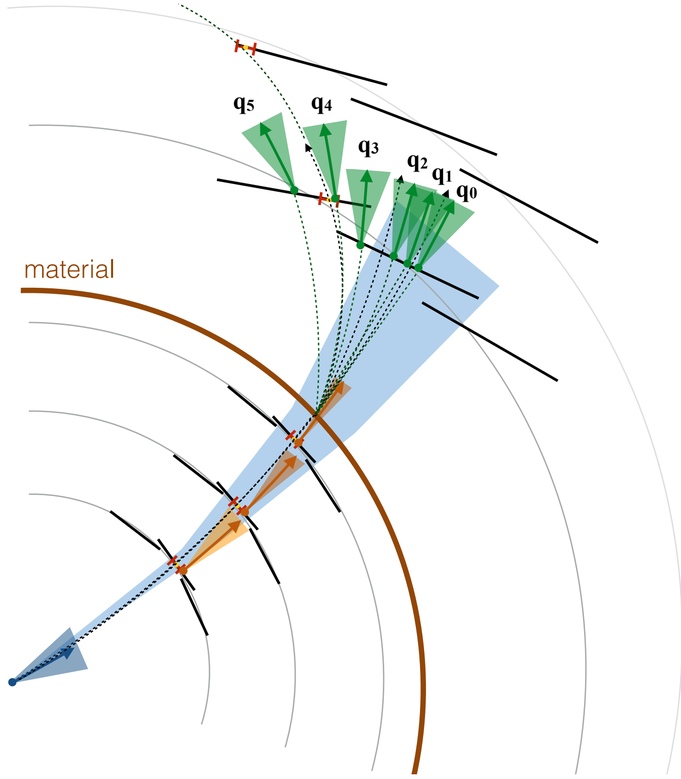




Dedicate track fitter: Gaussian Sum Filter

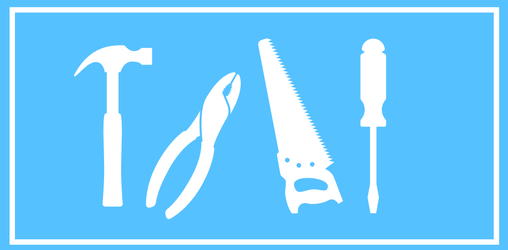
Multi-variant extension of the Kalman filter to model highly non-gaussian process noise from Bremsstrahlung.



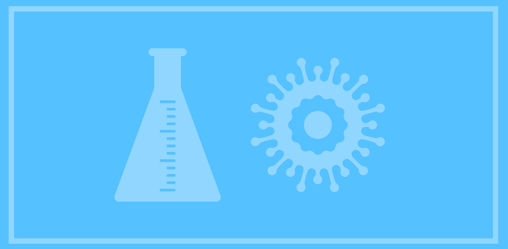


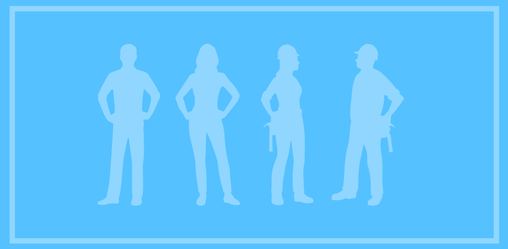
acts / Core / include / Acts

Fitting



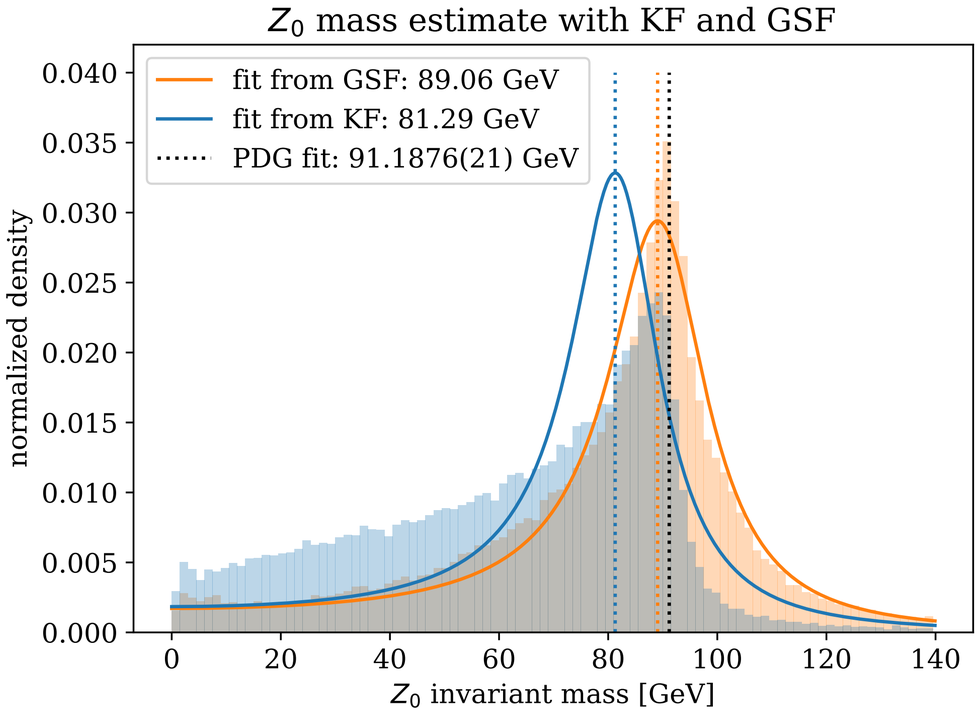
TOOLBOX





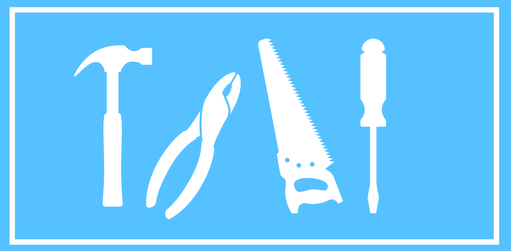
Dedicate track fitter: Gaussian Sum Filter

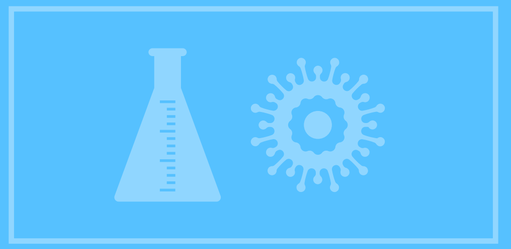
Does improve momentum estimates for electrons

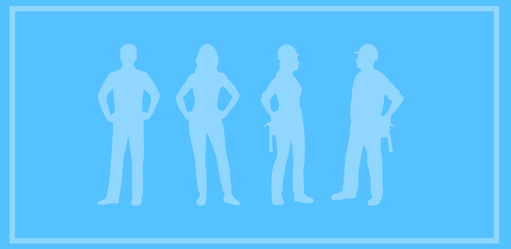


acts / Core / include / Acts

📁 Fitting



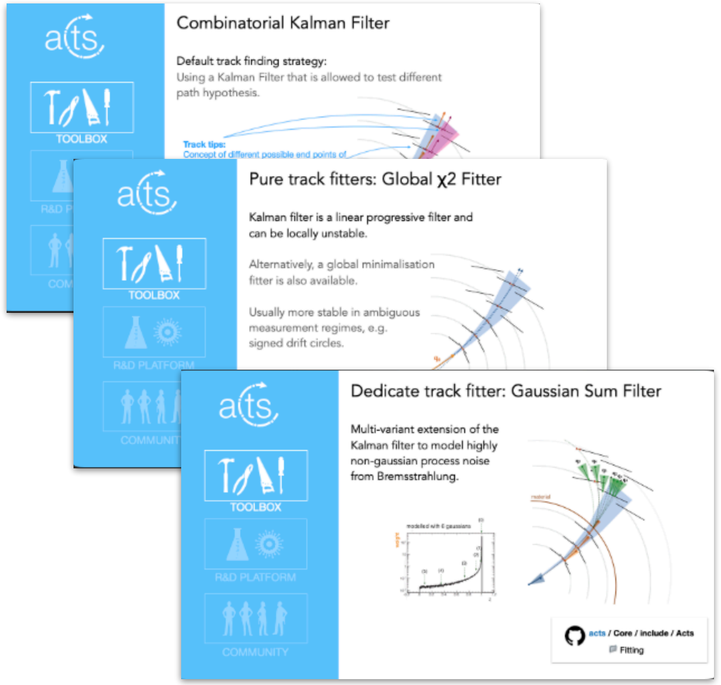




Requirement for fitters: propagation

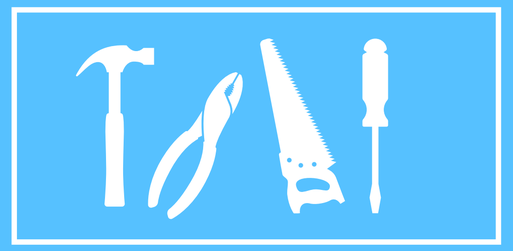
Track (and vertex) fitters rely on a correct transport of the track through the detector:

- precise **integration** of **equation of motion**
- adequate **handling** of **detector material**
- **predictive navigation** to find/identify sensitive detector elements

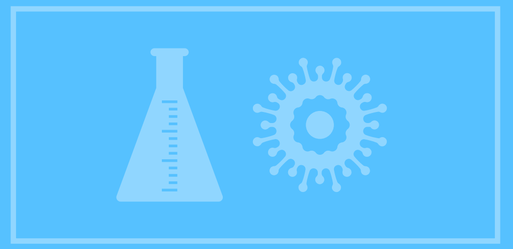


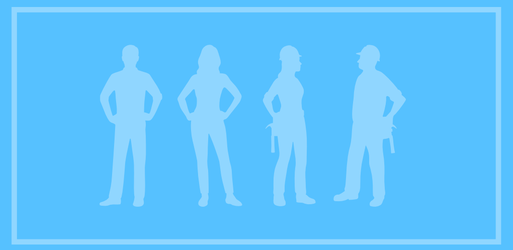
acts / Core / include / Acts

- Navigation
- Propagation



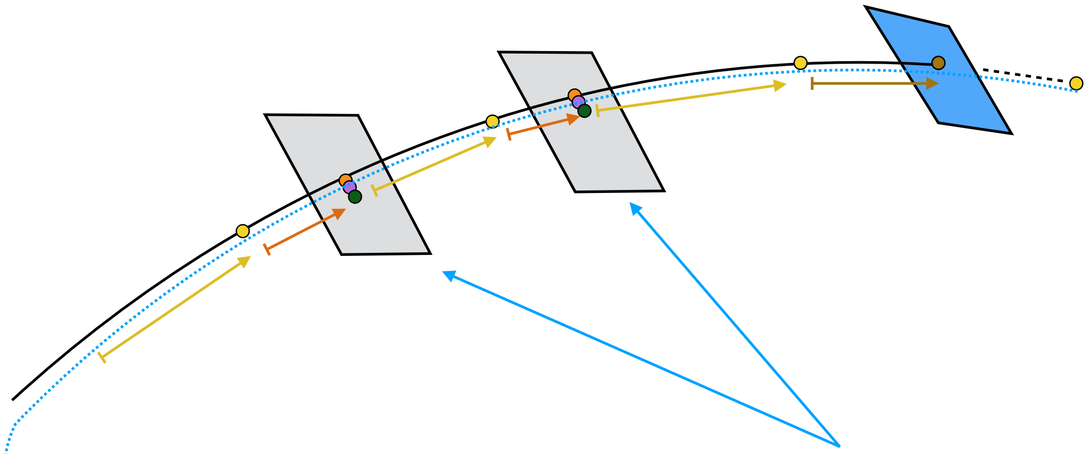
TOOLBOX





Propagation

Propagator:
Transport from one point to another,
extendable functionality with Actors



Navigator:
Talks to tracking geometry to provide
Surfaces, Portals, Material

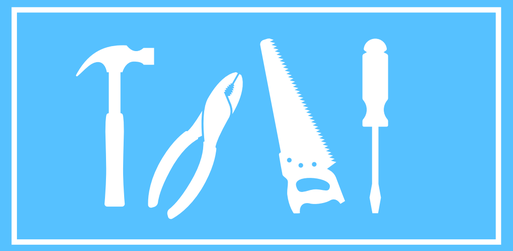
Stepper:
Field integration for parameter
and covariance transport:

- `StaightLineStepper`
- `AtlasStepper` (RKN)
- `EigenSteppen` (RKN)
- `SympyStepper` (RKN)

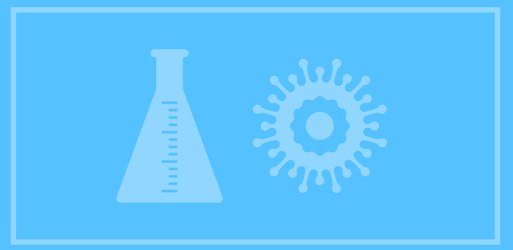
Magnetic field access needed

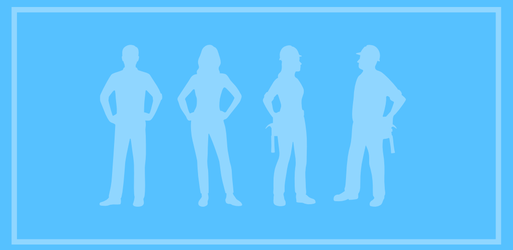
acts / Core / include / Acts

- EventData
- MagneticField
- Material
- Navigation
- Propagation



TOOLBOX





Ambiguity Solving

Historic name (from ATLAS) mainly trying to reduce duplication in the output candidate track collection:

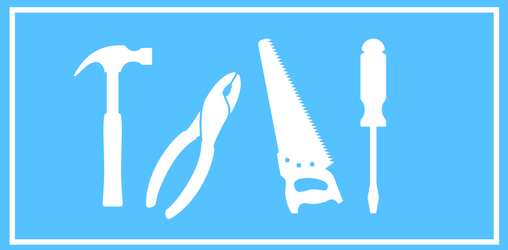
- eliminate duplicates (keep better one)
- eliminate/suppress fake tracks
- re-assign hits (requires re-fit)

Greedy | Score based | ML based

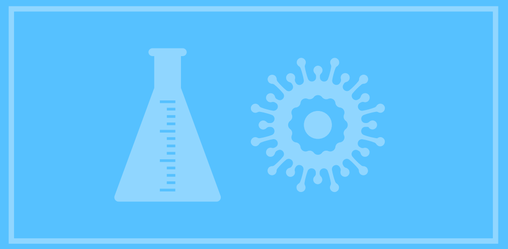
Hit re-assignment as in ATLAS' original ambiguity solver, is not yet supported.

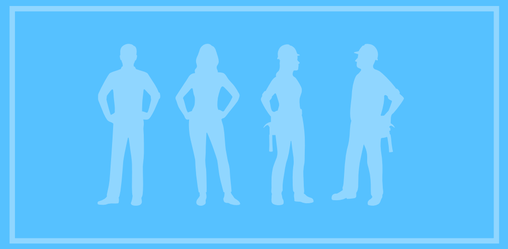
acts / Core / include / Acts

AmbiguityResolution



TOOLBOX



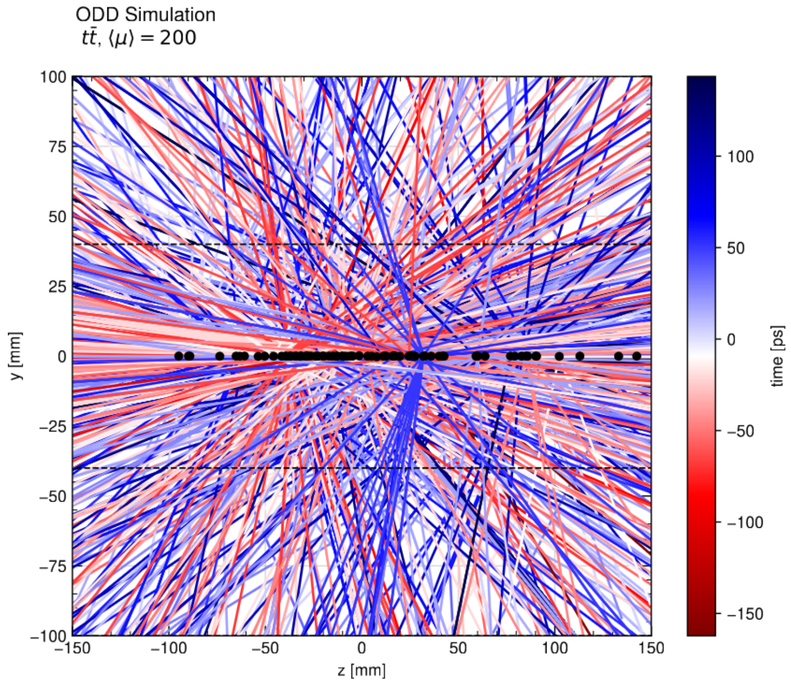


Vertex reconstruction

Full primary vertex reconstruction suite including time fitting

Iterative Finding

vertices are found one by from seeds
- unique track to vetrex
- Ideal for low vertex multiplicity/ density

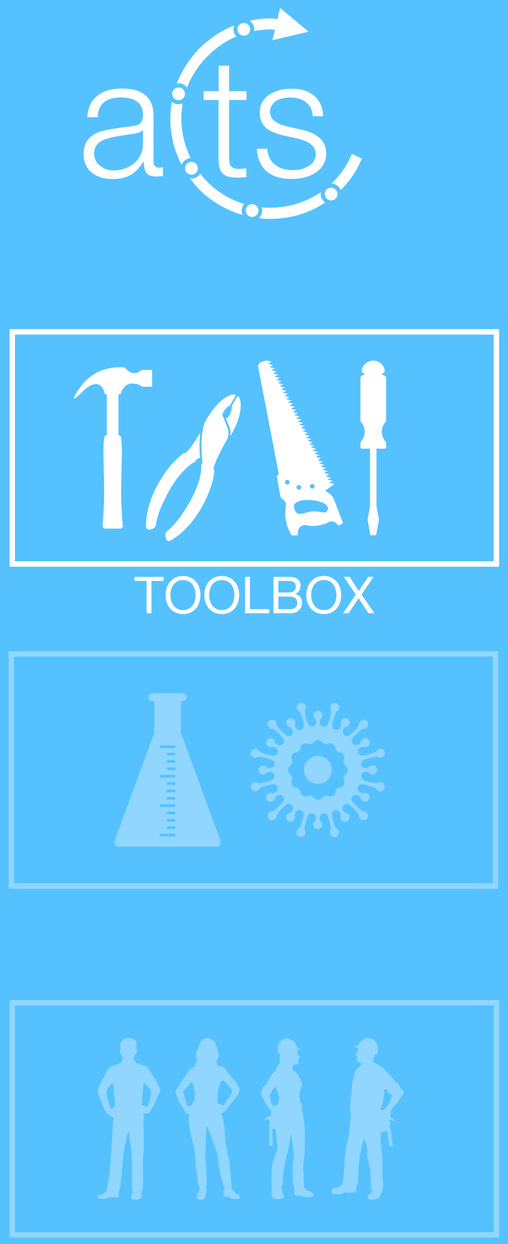


Multi Adaptive Finding

vertices are found simulatously from seeds:
- tracks can be multiply assigned to vertices with different weights
- More performant for high vertex multiplicity/density

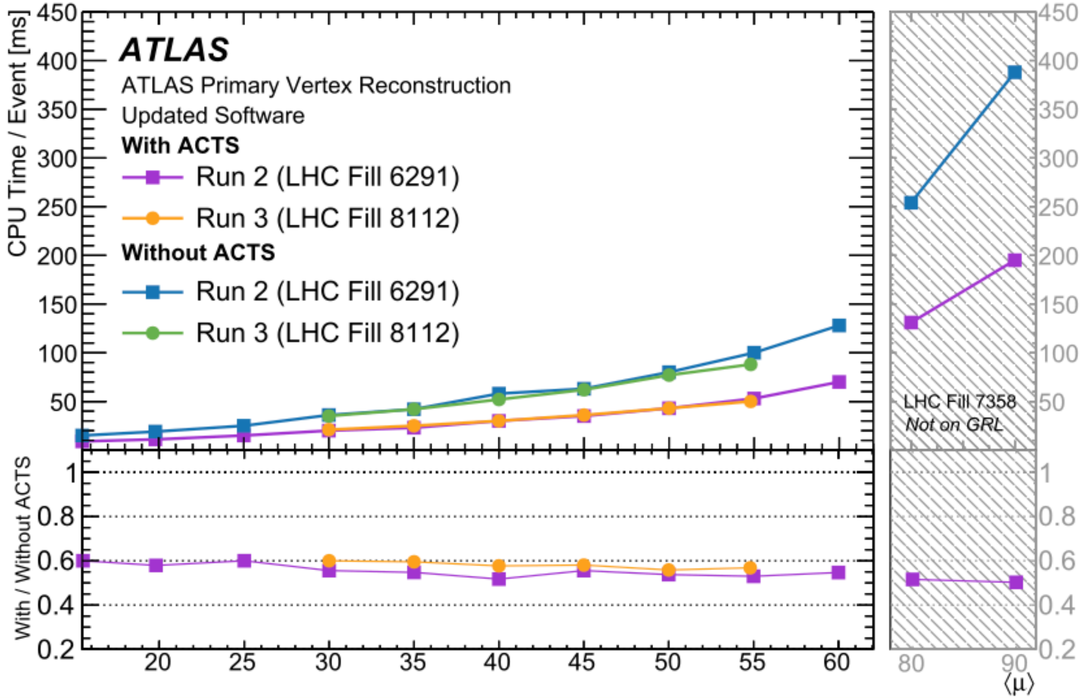
acts / Core / include / Acts

📁 Vertexing



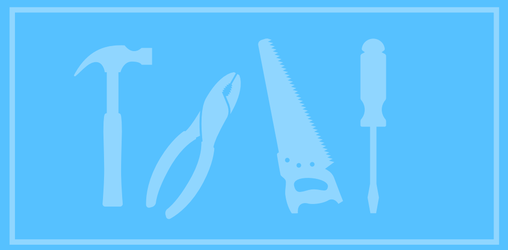
Vertex reconstruction

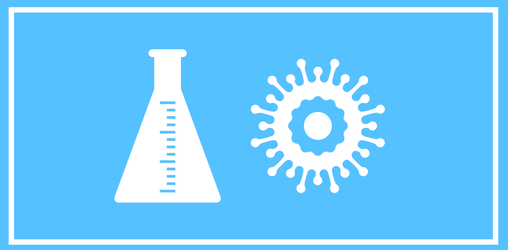
First ACTS module in ATLAS (for Run-3 already)



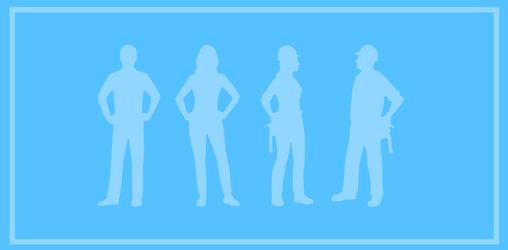
ACTS has already many tools that could be reused for secondary vertex reconstruction.

Pointing, mass constrains and decay chain fitting is however not (yet) implemented.





R&D PLATFORM

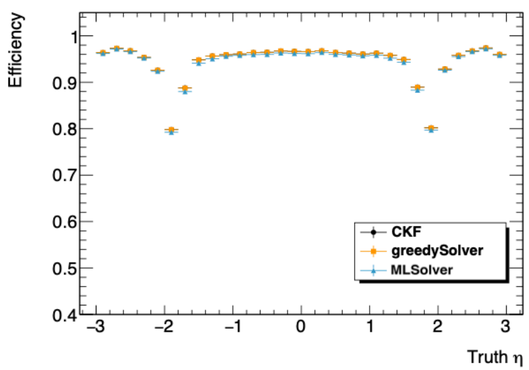


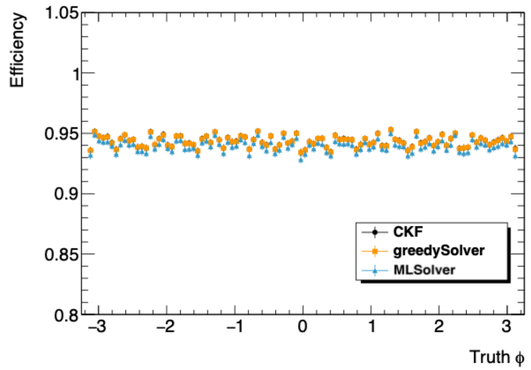
R&D Examples

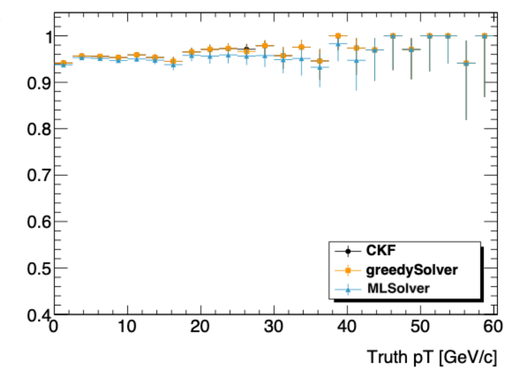
plug-and-play framework

ML assisted track finding modules

ML based ambiguity solving



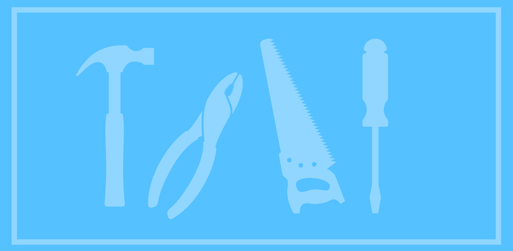


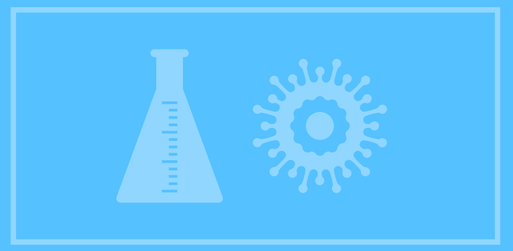


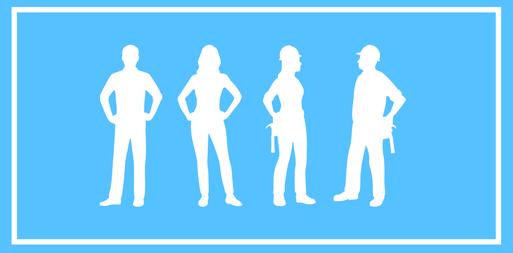
The framework should allow you to integrate your R&D algorithm in a relatively painless manner into an existing track reconstruction chain.

acts / Examples

Algorithms/TrackFindingML







COMMUNITY

Developers meeting: PR recap

acts-project/acts: PRs merged between 2025-03-25 and 2025-04-01 I

- **feat: Allow turning off Layer center of gravity** (#4150)
  by @paulgessinger, ✅ reviewed by @asalzburger, merged on 2025-03-25
- **fix: Fix vertex id grouping in 'ParticleTrackParamExtractor'** (#4148)
  by @andiwand, ✅ reviewed by @AJPfleger, merged on 2025-03-25
- **refactor: Add a *consuming* data handle that removes a key** (#4135)
  by @paulgessinger, ✅ reviewed by @andiwand, merged on 2025-03-25
- **fix: Improve and fix some interaction code** (#4133)
  by @andiwand, ✅ reviewed by @benjaminhuth, merged on 2025-03-25
- **fix: Increase the surfaceCandidateIndex in the Detector Navigator an re initialize navigation state in case of unreachable portal** (#4134)
  by @dimitra97, ✅ reviewed by @andiwand, merged on 2025-03-25
- **fix: Fix link to spack guide** (#4144)
  by @cgleggett, ✅ reviewed by @paulgessinger, merged on 2025-03-25
- **refactor: Optionally write track info in 'VertexNTupleWriter' in Examples** (#4146)
  by @andiwand, ✅ reviewed by @paulgessinger, merged on 2025-03-26

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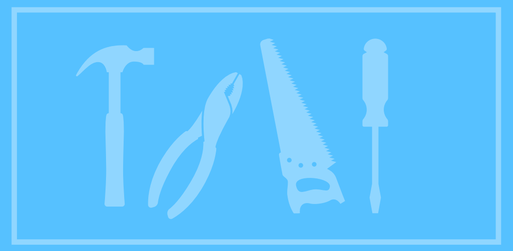
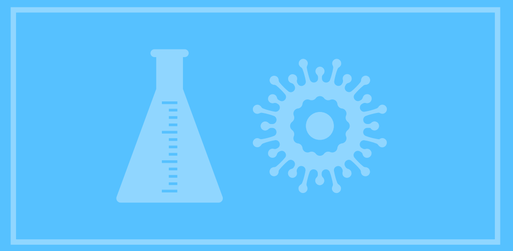
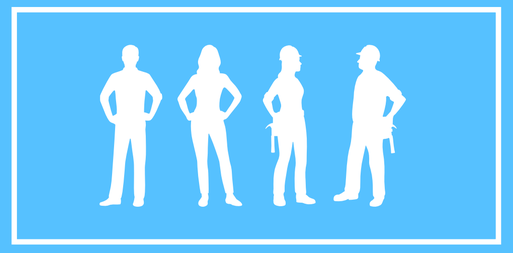
Walk through merged PR since the last meeting, discuss if necessary

The dedicated acts-parallelisation meeting follows the same structure







COMMUNITY

Developers meeting: Open PR/issues

acts-project/acts: Open PRs I

- **refactor(Examples) - Replace the drift circle & simHit EDM by the MuonSpacePoint & MuonSegmentEDM** (#4180)
  by @junggjo9, ✅ comment by @coderabbitai[bot], updated on 2025-04-01
- **feat: Use 80-bit high-precision floating point** (#4181)
  by @stephenswat, ⚠️ no reviewer, updated on 2025-04-01
- **ci: Spack** (#3980)
  by @paulgessinger, ✅ comment by @paulgessinger, updated on 2025-04-01
- **feat: simpler 2d/3d calculation** (#4169)
  by @asalzburger, ✅ comment by @coderabbitai[bot], updated on 2025-04-01
- **chore: Zoom in on vertex position in ttbar physmon** (#4178)
  by @paulgessinger, ✅ reviewed by @andiwand, updated on 2025-04-01
- **refactor(Examples): Untemplate Generic Detector construction** (#4176)
  by @paulgessinger, ✅ comment by @coderabbitai[bot], updated on 2025-04-01
- **feat: Add Error message in SurfaceArrayNavigationPolicy** (#4177)
  by @ldamenti, ✅ comment by @coderabbitai[bot], updated on 2025-04-01

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Highlight developments, discuss, assign reviewers

The dedicated acts-parallelisation meeting follows the same structure (for traccc & friends)