The ACTS common tracking software

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Université de Genève

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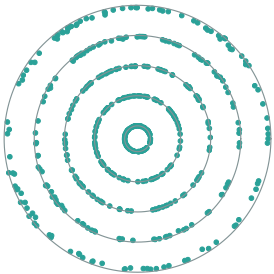
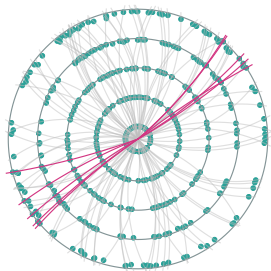
What is ACTS?

From hits



$\Rightarrow$

...to tracks



A Common Tracking Software

- Standalone C++-based tracking package
- Based on ATLAS tracking software
- Primary goal: ATLAS run 3 and beyond

From ATLAS to ACTS

Existing ATLAS tracking code

- Well-tested
- Known performance

but:

- Single-threaded,
- Historically grown structure
- Rigid

Towards ACTS

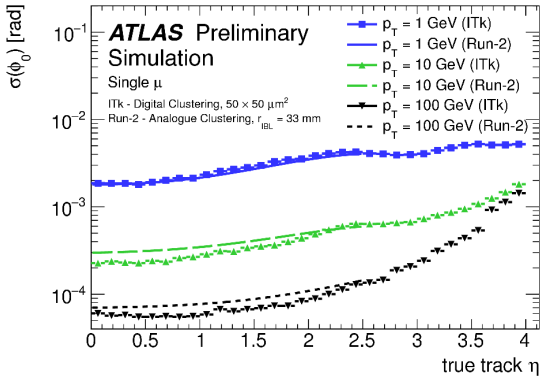
- Review design
- Upgrade to modern C++14/17
- Const-correctness and concurrent execution
- Unit and regression tests

Why a standalone package?

Allow cleanup and optimization:

1. Physics performance: Keep or improve
2. Computational complexity: Reduce
3. Usability (user complexity): Improve

Simplify algorithmic R&D



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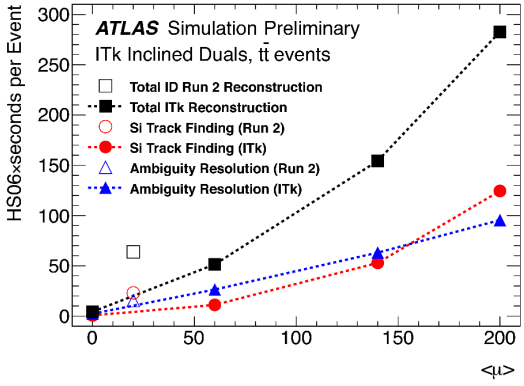
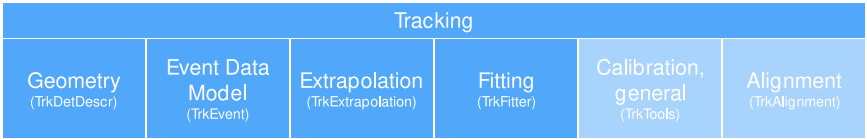
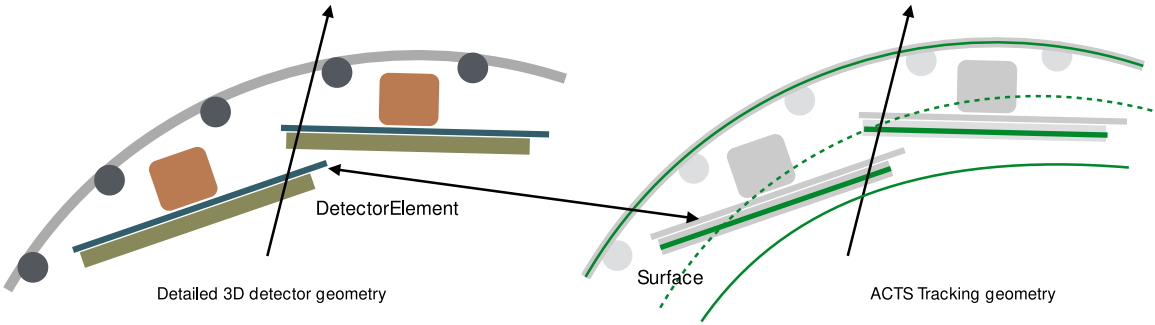


Components


Tracking
Geometry
(TrkDetDescr)
Event Data Model
(TrkEvent)
Extrapolation
(TrkExtrapolation)
Fitting
(TrkFitter)
Calibration, general
(TrkTools)
Alignment
(TrkAlignment)

Tracking geometry



Event data

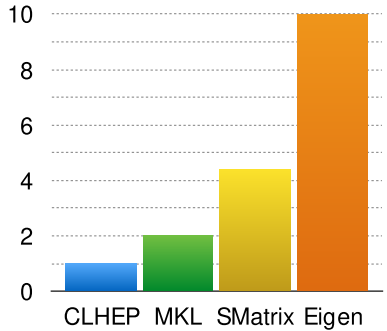
Track parameters

- Acts::TrackParameters
- Acts::SingleBoundParameters
- Acts::SingleCurvilinearParameters

Measurements

- Acts::Measurement
- Acts::CalibratedMeasurement

Based on Eigen library
Alway use fixed-size matrices

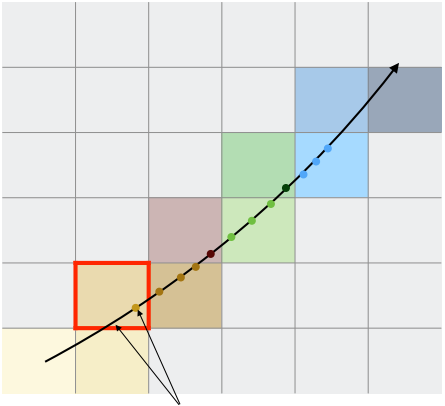


ATLAS LS1 performance comparison, 5x5 matrix multiplication

Magnetic field(s)

Cache magnetic field cell

- Simulation time reduction up to 20 %
- Reconstruction time reduction of few %
- Local copy reduced access to global field map

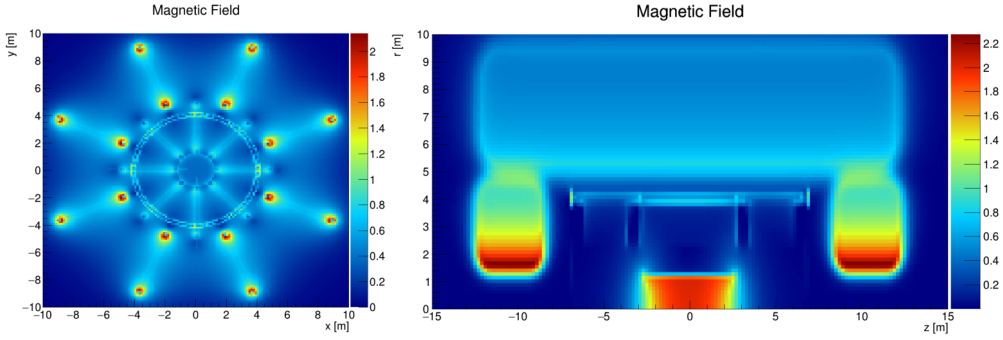


Magnetic field(s)

Extrapolation test with different field maps:

- ATLAS solenoid + torroid map
- FCC-hh map

Example: ATLAS



Propagation and extrapolation

Propagator

- Just the transport
- Multiple Runge-Kutta implementations: original ATLAS, Eigen
- Templated implementation extendable with actors

Extrapolator

- Uses propagator
- Geometry navigation

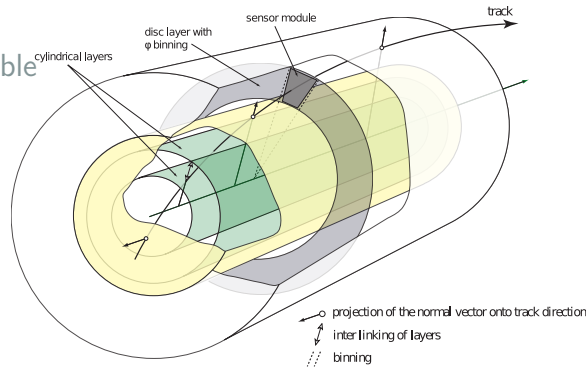


Fig. from A. Salzburger

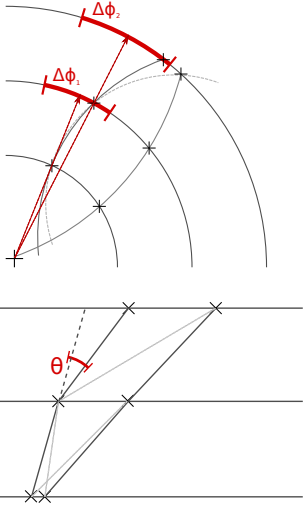
Track finding / fitting

Finding

- Simplistic combinatorial seed finder
- Transcribed ATLAS seed finder (in-progress)

Fitting

- Prototype Kalman filter



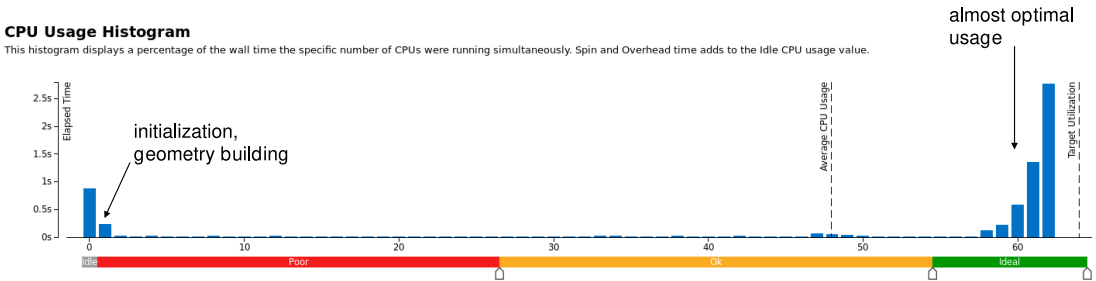
Guidelines:

- Data is shared XOR mutable
- Enforce const-correctness

ACTS framework

- Minimal event processing
- Parallelized using OpenMP

Running on Intel Xeon e5-2698, 32 cores, 64 threads (CERN OpenLab)



Unit and regression tests

Why?

- Verify at component level
- Ensure expected behaviour
- Provide developer feedback
- Test new APIs

  Also:
- Multi-threaded vs. single-threaded
- Regression vs. ATLAS code

Example

```
1  BOOST_AUTO_TEST_CASE(CylinderBoundsProperties)
2  {
3    // generate objects w/ well-known parameters
4    CylinderBounds cb1(...);
5    CylinderBounds cb2(...);
6    BoundaryCheck  withTolerance(true, true, 0.1, 0.1);
7
8    // test points
9    Vector2D origin{0., 0.};
10   Vector2D atPiBy2{M_PI / 2., 0.0};
11
12   // check some functionality
13   BOOST_TEST(cb1.inside(atPiBy2, withTolerance) == true);
14   BOOST_TEST(cb1.inside(origin, withTolerance) == true);
15   BOOST_TEST(cb2.inside(origin, withTolerance) == false);
16   ...
17 }
```

Test coverage

Core/include/ACTS/EventData/ParticleDefinitions.hpp		0.0 %	0 / 15	0.0 %	0 / 24
Core/include/ACTS/EventData/SingleBoundTrackParameters.hpp		71.4 %	35 / 49	41.8 %	38 / 91
Core/include/ACTS/EventData/SingleCurvilinearTrackParameters.hpp		76.7 %	33 / 43	43.3 %	39 / 90
Core/include/ACTS/EventData/SingleTrackParameters.hpp		72.0 %	36 / 50	47.4 %	36 / 76
Core/include/ACTS/EventData/TrackParametersBase.hpp		66.7 %	6 / 9	100.0 %	0 / 0
Core/include/ACTS/EventData/TransportJacobian.hpp		0.0 %	0 / 1	100.0 %	0 / 0
Core/include/ACTS/EventData/detail/coordinate_transformations.hpp		100.0 %	28 / 28	53.3 %	32 / 60
Core/include/ACTS/EventData/detail/initialize_parameter_set.hpp		100.0 %	14 / 14	50.0 %	6 / 12
Core/include/ACTS/EventData/detail/make_projection_matrix.hpp		100.0 %	14 / 14	50.0 %	81 / 162
Core/include/ACTS/EventData/detail/residual_calculator.hpp		100.0 %	11 / 11	100.0 %	0 / 0
Core/include/ACTS/Layers/ConeLayer.hpp		100.0 %	5 / 5	50.0 %	3 / 6
Core/include/ACTS/Layers/CylinderLayer.hpp		100.0 %	5 / 5	50.0 %	3 / 6
Core/include/ACTS/Layers/DiscLayer.hpp		100.0 %	5 / 5	50.0 %	3 / 6
Core/include/ACTS/Layers/GenericApproachDescriptor.hpp		100.0 %	32 / 32	46.0 %	23 / 50
Core/include/ACTS/Layers/Layer.hpp		73.5 %	25 / 34	8.3 %	2 / 24
Core/include/ACTS/Layers/NavigationLayer.hpp		80.0 %	8 / 10	50.0 %	3 / 6
Core/include/ACTS/Layers/PlaneLayer.hpp		100.0 %	5 / 5	50.0 %	3 / 6
Core/include/ACTS/Layers/		100.0 %	2 / 2	100.0 %	0 / 0

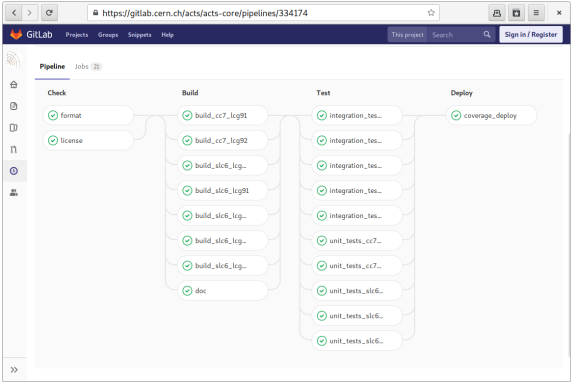
Continuous integration setup

- Tests are useless if not run
- Different developer/user environments

→ Use CERN Gitlab continous integration

Implementation

- Minimal Docker images
- LCG Releases via CVMFS
- Consistent w/ LXPLUS

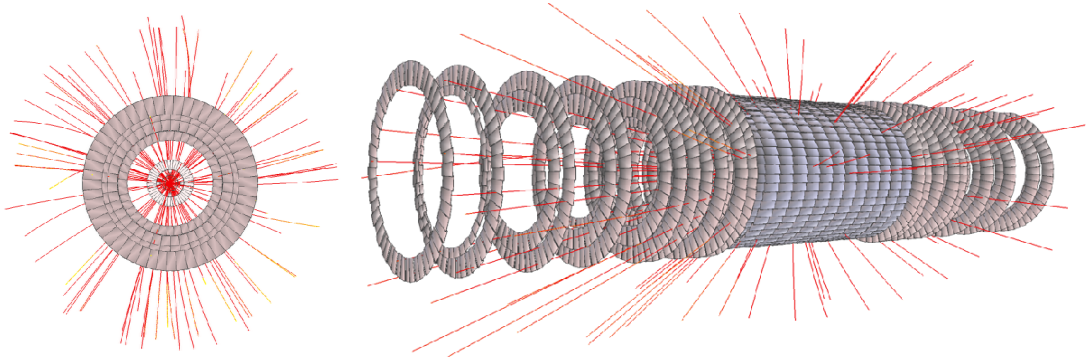


Continuous integration platforms

Distribution	LCG Release	Compiler	Build type	Comment
Scientific Linux CERN 6	LCG_88	GCC 6.2	Release	legacy build
	LCG_91	GCC 6.2	Debug	default build
	LCG_91	LLVM 4.0	Release	
	LCG_92	GCC 6.2	Release	
CERN CentOS 7	LCG_91	GCC 7.0	Release	
	LCG_92	GCC 7.0	Release	

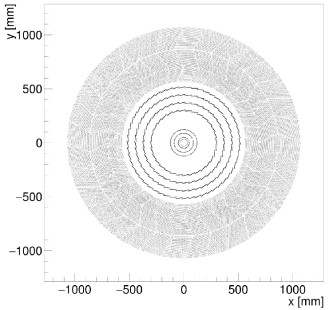
Important: all dependencies/versions provided by LCG release.

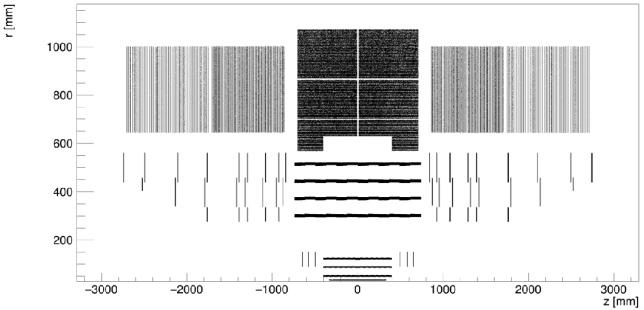
Current silicon detector



Geometry via GeoModel in Athena 21.0.39
Magnetic field from field service

Current inner detector



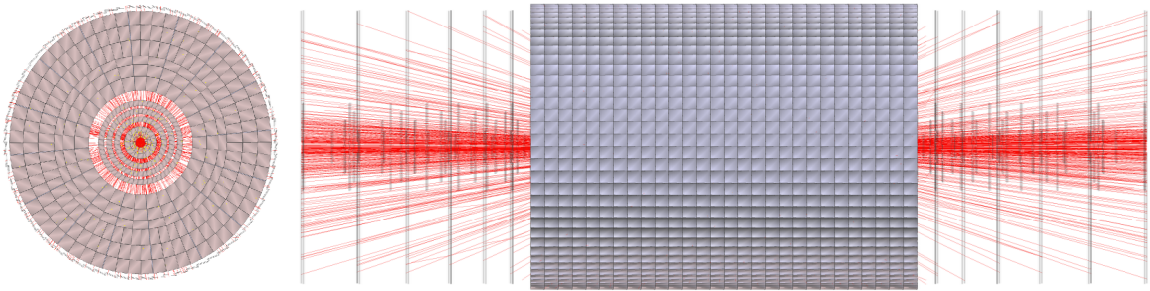


Geometry via GeoModel in Athena 21.0.39
Magnetic field from field service

ATLAS Athena integration (cont'd)

P. Gessinger

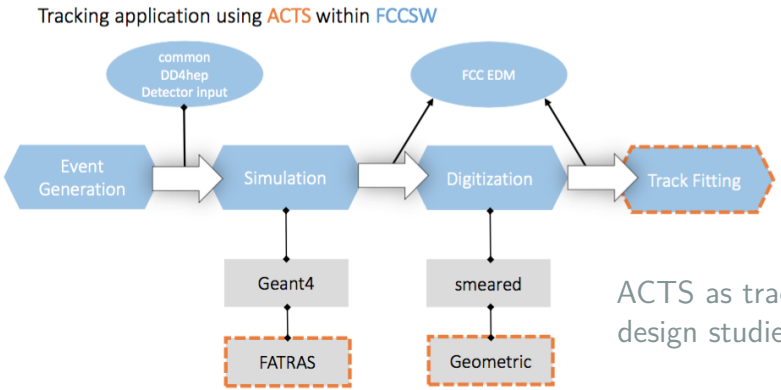
Upgrade inner detector (ITk)



Geometry via from GeoModel in Athena 20.20
Some problems with pixel endcaps

FCC(hh) integration

J. Hdrinka

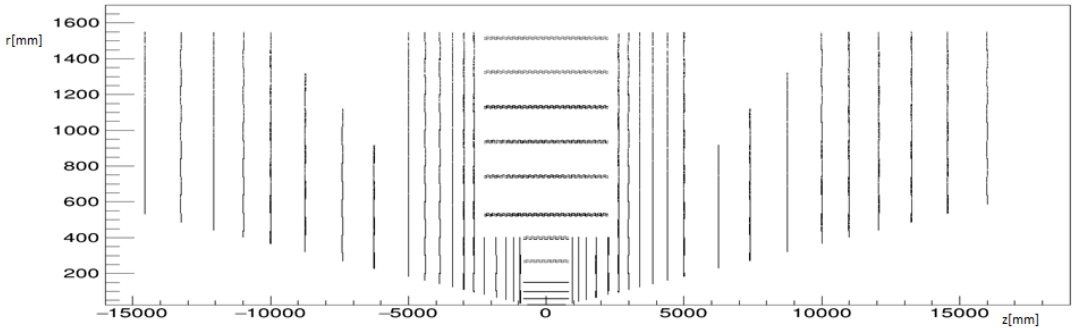


ACTS as tracking toolkit in FCC(hh) design studies

- Gaudi for event processing
- DD4hep as geometry description
- Geant4 for simulation

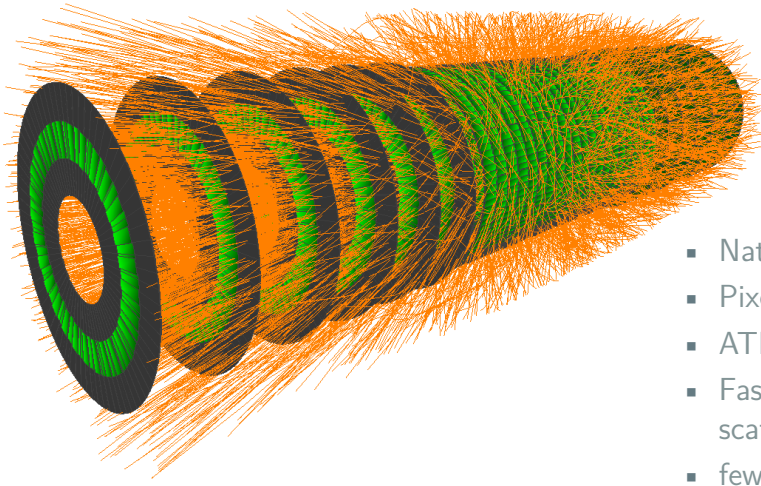
FCC(hh) integration (cont'd)

J. Hdrinka



Magnetic field provided by FCCSW

Tracking machine learning challenge

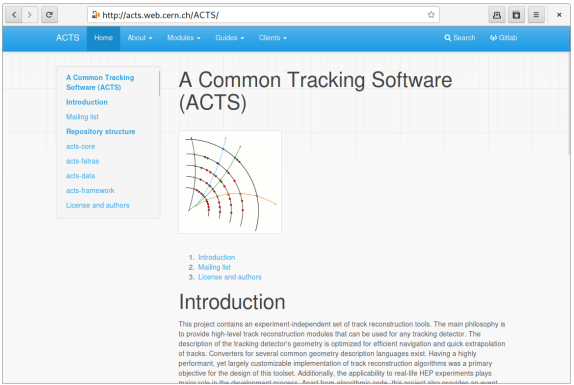


- Native ACTS geometry
- Pixels, strips in barrels and disks
- ATLAS-like magnetic field
- Fast simulation w/ material, scattering, nuclear interactions
- few Hz generation rate

Contributors and website

Contributors:

- Paul Gessinger
- Hadrien Grasland
- Julia Hdrinka
- Moritz Kiehn
- Fabian Klimpel
- Robert Langenberg
- Shaun Roe
- Andreas Salzburger
- Valentin Volkl



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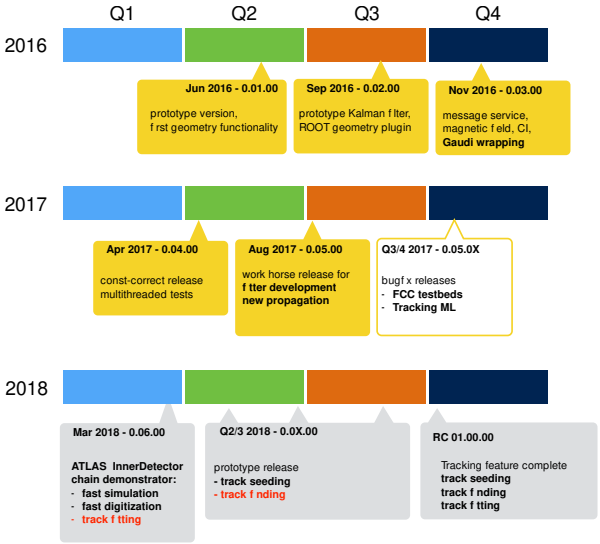
Tentative timeline



ATLAS internal review last week

Plans

- This year:
  standalone inner detector prototype
- Medium term:
  ATLAS integration for LHC run 3

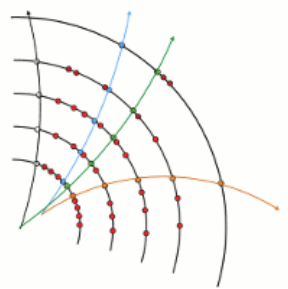
Summary

Status

- Standalone tracking package
- Derived from ATLAS tracking
- Now: concurrent, modern code base

Upcoming

- New propagator
- Inner detector prototype



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