

Experience of using ACTS to implement GBTS as a new seeding method for the ATLAS ITk

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ATLAS ITk

ATLAS Upgrade

- **High Luminosity-LHC:**
Run 4+ of LHC at higher luminosity
- Key dates:
 - Long Shutdown 2: 2026-2029
 - Run 4: 2030-2033
- Upgrades to detector and software
- TDAQ System:
 - Hardware & software triggers
 - Increase trigger output rate 3 → 10 kHz

ATLAS DETECTOR LS2 UPGRADES

MUON NEW SMALL WHEELS (NSW)

Installed new muon detectors with precision tracking and muon selection capabilities. Key preparation for the HL-LHC.



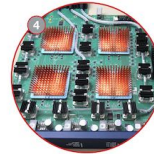
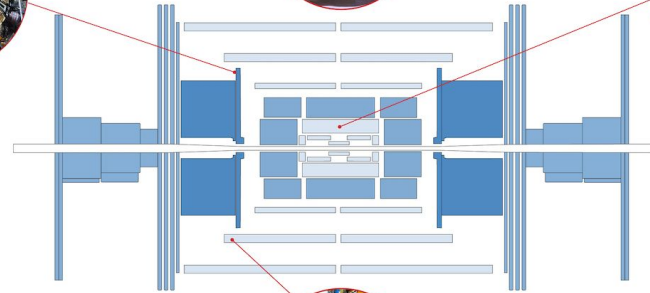
NEW READOUT SYSTEM FOR THE NSWs

The NSW system includes two million micromega readout channels and 350 000 small strip thin-gap chambers (sTGC) electronic readout channels.



LIQUID ARGON CALORIMETER

New electronics boards installed, increasing the granularity of signals used in event selection and improving trigger performance at higher luminosity.



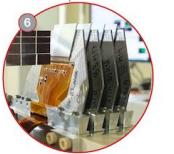
TRIGGER AND DATA ACQUISITION SYSTEM (TDAQ)

Upgraded hardware and software allowing the trigger to spot a wider range of collision events while maintaining the same acceptance rate.



NEW MUON CHAMBERS IN THE CENTRE OF ATLAS

Installed small monitored drift tube (sMDT) detectors alongside a new generation of resistive plate chamber (RPC) detectors, extending the trigger coverage in preparation for the HL-LHC.



ATLAS FORWARD PROTON (AFP)

Re-designed AFP time-of-flight detector, allowing insertion into the LHC beamline with a new "out-of-vacuum" solution.

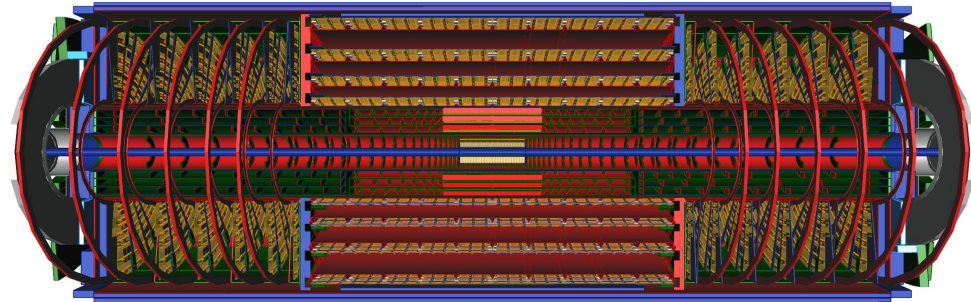
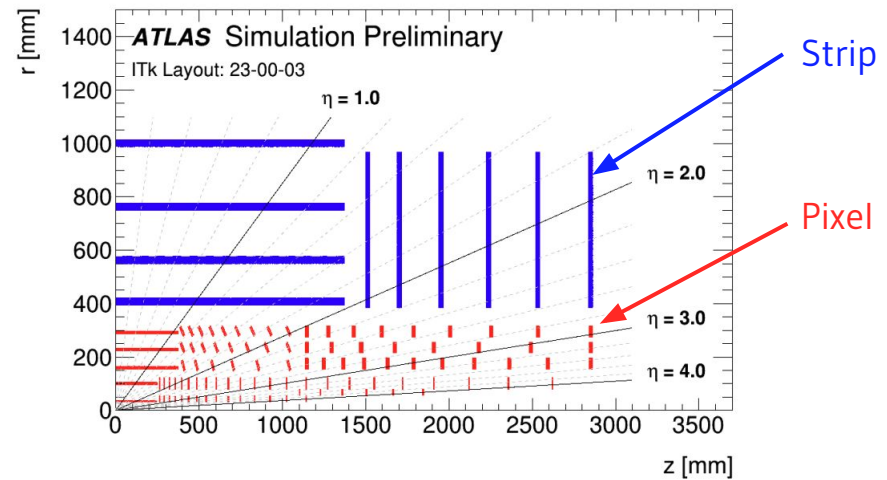
ATLAS Collaboration, ATLAS upgrades during LS2.

ITk

- New all silicon inner tracker (ITk)
- Increase to pileup, μ , interactions per crossing

Run 3 $\mu = 50$ \longrightarrow HL-LHC $\mu = 200$

- Predicted 300,000 detector hits per event
- Increase in computational complexity
- New tracking algorithms must be developed



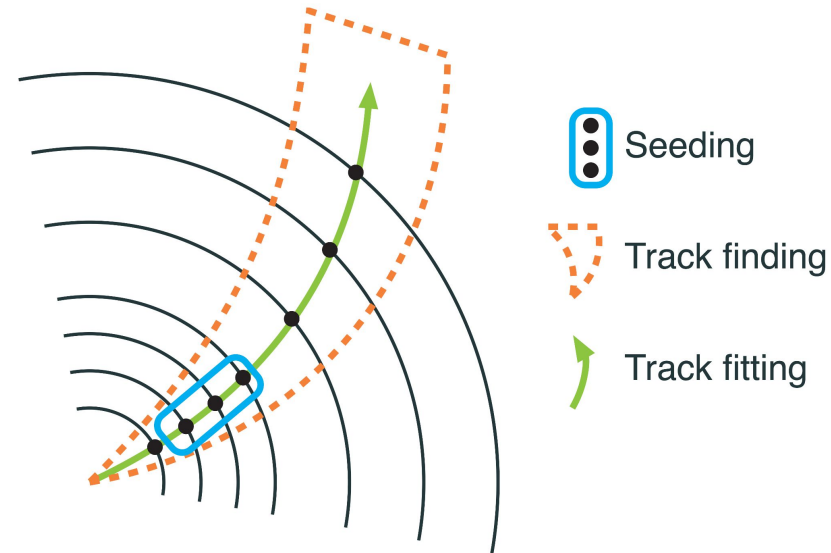
ATLAS Collaboration, *Expected tracking and related performance with the updated ATLAS Inner Tracker layout at the High-Luminosity LHC*. (2021)

Tracking background

Tracking algorithms aim to reconstruct particle tracks by connecting detector hits

Basic components:

- **Space points** (black dots): combination of hits and detector information
- **Seeds**: triplets of space points formed & filtered for those more likely to be from the same particle
- **Track candidates**: tracks made by extending seeds, then parameters estimated. Tracks filtered and fed into higher level reconstruction



ACTS, Tracking in a nutshell.

Tracking software



- Trigger & offline
- Requirements:
 - > High efficiency
 - > Low fake rate
 - > High precision track parameters
 - > Fast
- Software upgrade
 - > Maximise physics performance
 - > Modernise the software technology
 - > Support new processing accelerators (eg. GPU, FPGA)
 - > Ensure maintainability throughout the operation of the experiment
 - > Minimise CPU/RAM resource usage

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ACTS

ACTS

A Common Tracking Software ([github](#)) ([docs](#))

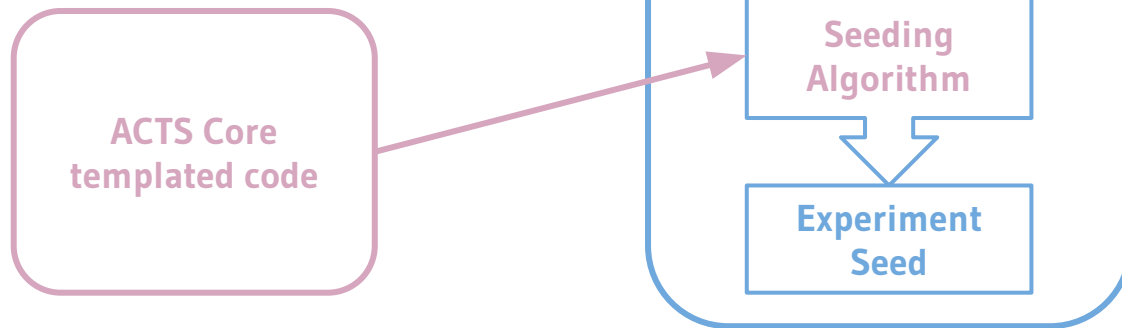
- Experiment-independent toolkit for (charged) particle track reconstruction in HEP experiment
- Preserve and develop LHC tracking software
- New and current ATLAS tracking software being integrated
- Benefits:
 - > Platform for research and development
 - > Experiment independent
 - > Thread-safety
 - > High performance
 - > Code maintainability



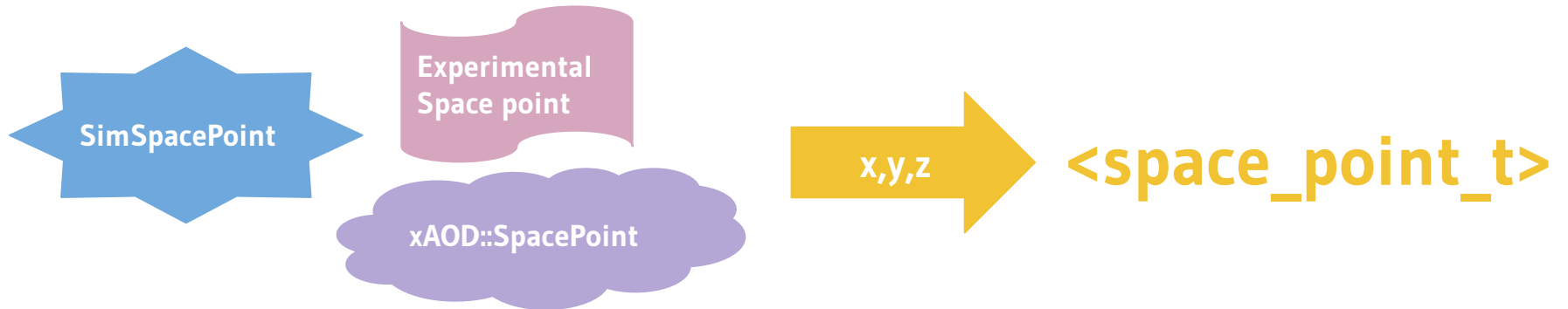
Code structure

Code structure:

- **Core:** experiment independent algorithms called directly from experiment software
- **Examples:** contains experiment geometry and algorithms to implement core algorithms to run standalone

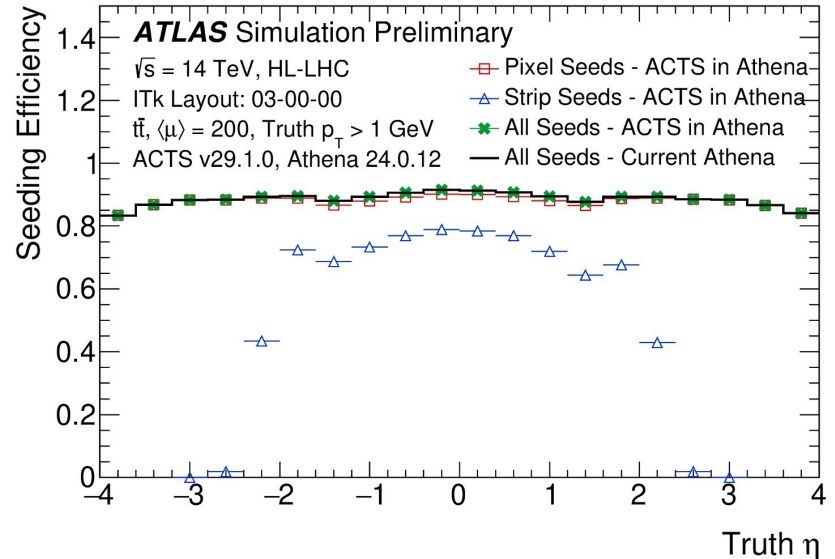


Templating



ACTS for ITk Performance Results

- Example use for ATLAS ITk
- Comparing to Athena - ATLAS software
- Latest public results
- Connecting The Dots 2023 (Paul Gessinger)
- Seeding:
 - > Reimplementation of ATLAS seeding
 - > Reproduces 1-1 identical seeds
 - > ~10% slower: ongoing optimization



ATLAS Collaboration, *Status of the ACTS Integration for Phase-II ATLAS Track Reconstruction.* (2023)

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GBTS Experience

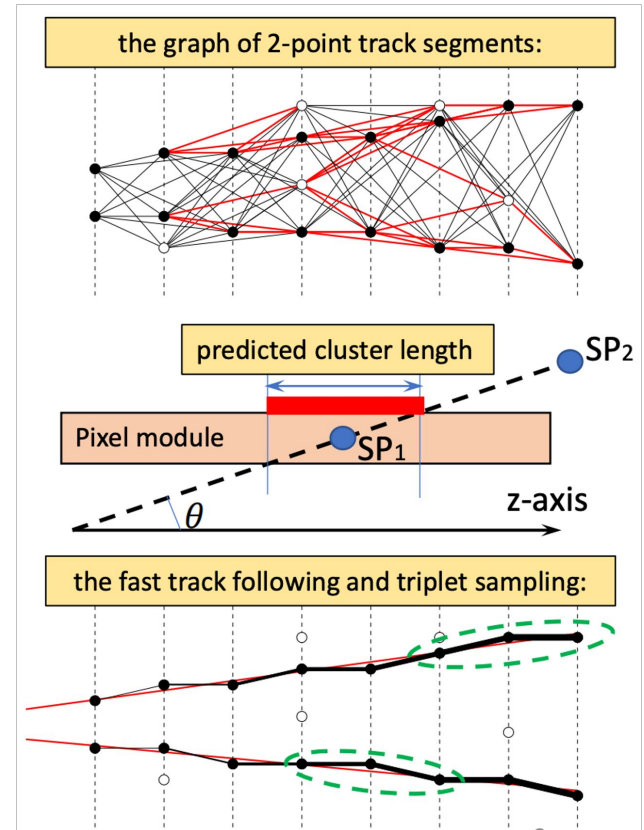
GBTS

Algorithm Details

HLT Algorithm originally developed for Athena (Dmitry Emelianov)

Just looking at seeding algorithm - **Graph Based Track Seeding**

- Takes input of relevant detector geometry information
- **Graph building:** A graph of two pixel space point track segments, known as edges, is created, based on a layer linking scheme[†]
- Number of **edges reduced** using a machine learning classifier. Uses cluster length to predict range of probable angles of inclination
- **Triplet making:** Fast track candidate discovery done using track following
- Triplets of space points are **sampled** from these to generate 3-spacepoint track seeds- long term want to pass on tracklets

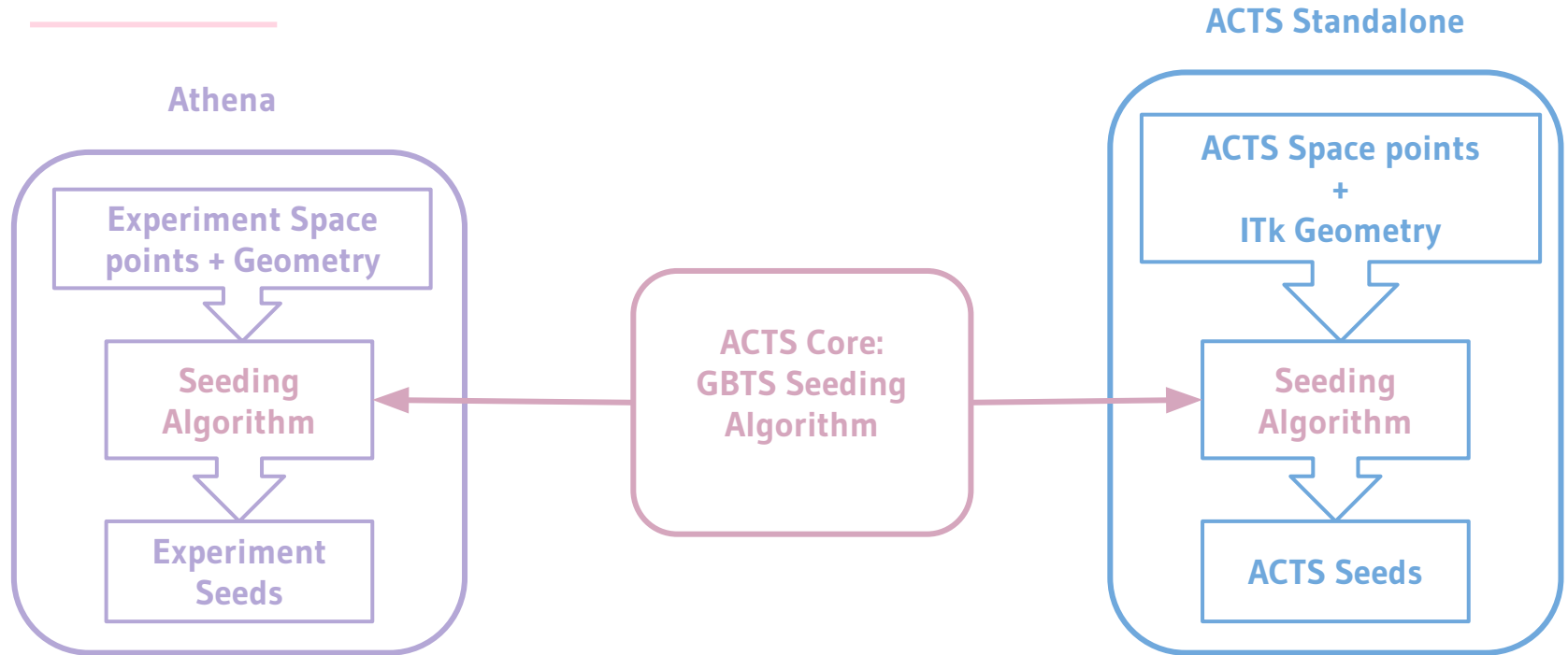


Dmitry Emelianov, *The FASTrack solution*, (2019)

[†] Backup slides

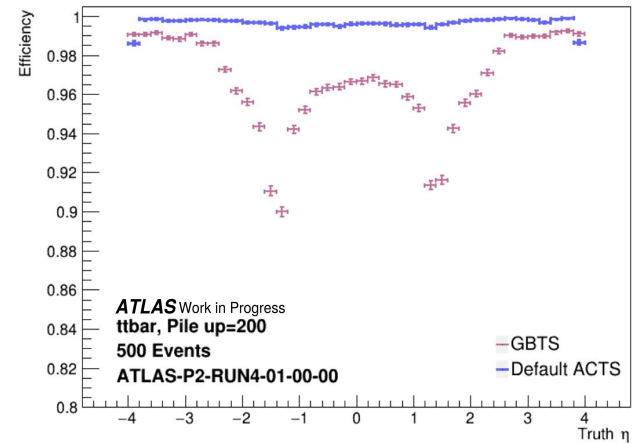
*Implementation
experience*

Workflows

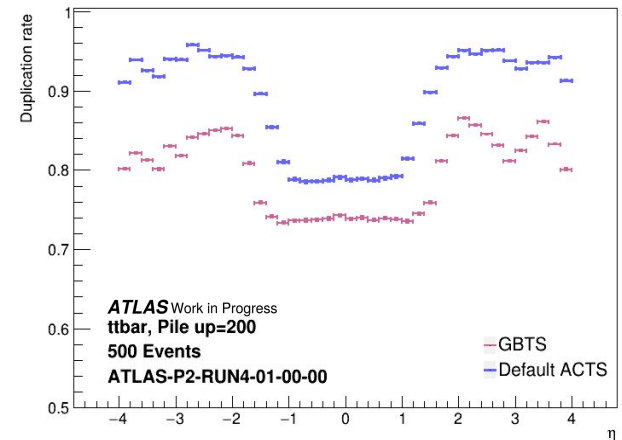


ACTS Standalone

- Running in ACTS Standalone
- Examples implementation on **ITk geometry**
- Comparing **ACTS default** and **GBTS** seeding
- Seeding Tracking efficiency = $n_{\text{MatchedParticles}} / n_{\text{AllParticles}}$



Duplication rate



Athena Implementation

- Athena is ATLAS software
- Implementation in Athena workflow will allow for direct comparison to original algorithm in Athena
- Ongoing development

Personal Experience

Thoughts on ACTS from implementation experience:

- Clear documentation
- Supportive and active community
- Collaboration and sharing of knowledge
- Code can be updated and maintained in ACTS Core
- Templating- algorithm changes should not affect experimental implementations

Summary

- ATLAS ITk:
 - > New inner tracker for ATLAS Run4+
 - > Increased tracking complexity
- ACTS:
 - > Platform for research and development
 - > Experiment independent
 - > Code maintainability
- GBTS experience:
 - > Algorithm in core
 - > Implementation with ITk geometry
 - > Running in Athena software
 - > Ongoing improvements

Questions?

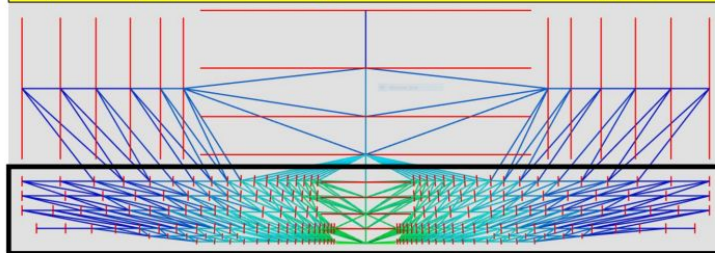
Backup

Layer linking

Probabilistic layer linking

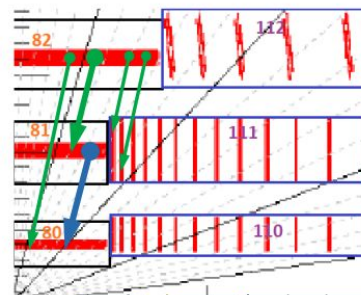
- Track movement from layer to layer is modelled as a Markov process and state transition probabilities are estimated using simulated reference tracks
- Layer linking graph is obtained after applying a cut of 10^{-5} on transition probabilities

Layer linking graph for Fastrack algorithm trained on $t\bar{t}$ MC data, $p_T \geq 1\text{GeV}$



07/06/2022

EF Tracking Weekly Meeting



	from	to	probability
25	A	B	C
25	81000	80000	1
26	82000	81000	0.941664
27	82000	80000	0.020266
28	82000	101000	0.01487
29	82000	111000	0.014688
30	82000	111001	0.004276
31	82000	101001	0.004237
32	83000	82000	0.977832
33	83000	81000	0.022168
34	84000	83000	0.976277
35	84000	82000	0.023723

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Dmitry's slides