Winter Nuclear and Particle Physics Conference 2022

Search for Long lived Particles with innovative tracking algorithm in the ATLAS Experiment

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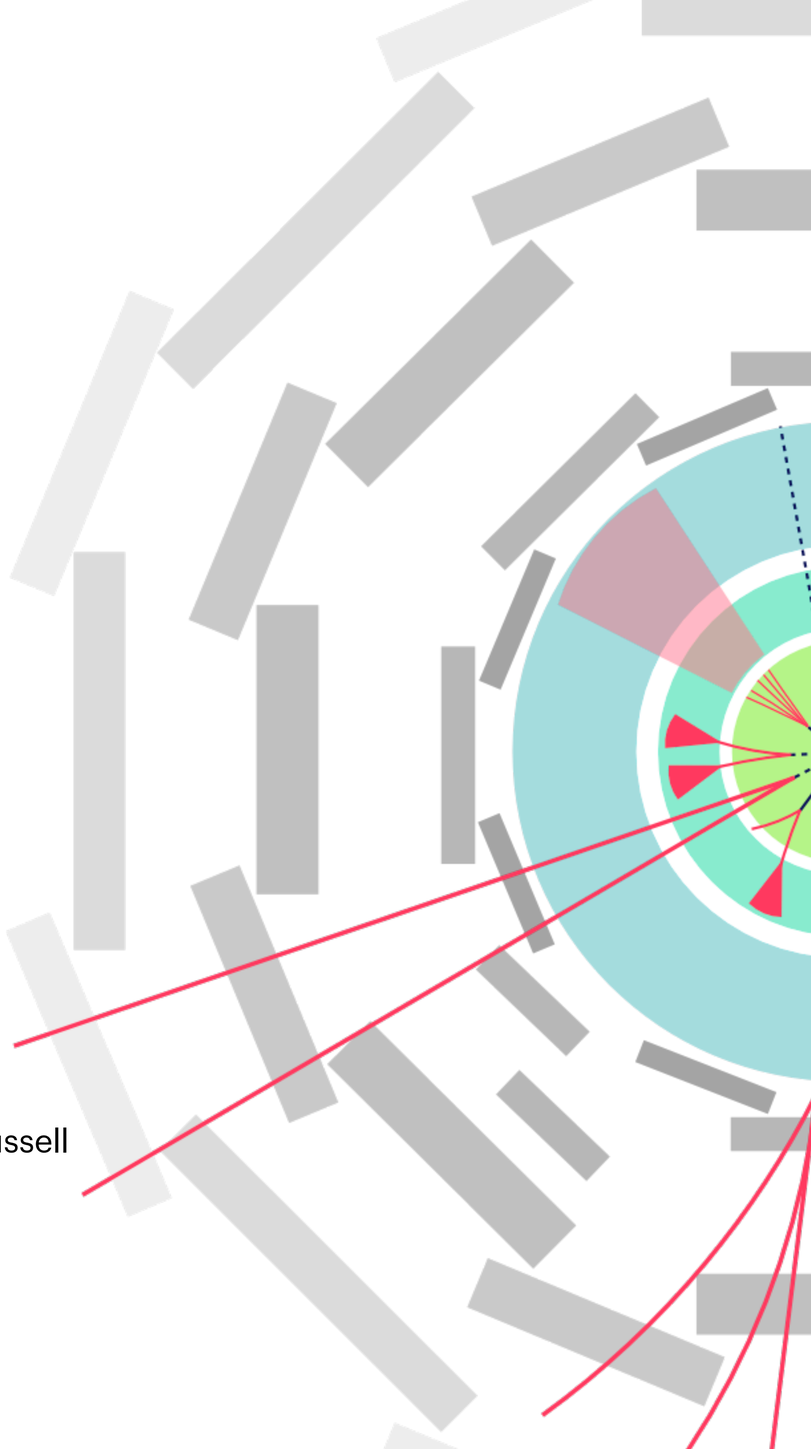

Graphics taken from : H. Russell

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ATLAS EXPERIMENT

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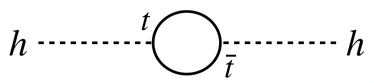
Where is the new physics?

The discovery of Higgs Boson completed the missing piece of the **Standard Model** but still the whole framework is **not yet complete**: observational and theoretical open questions remain.

Dark matter?

Higgs mass too light?



Magnetic dipole moment of a muon

LHC experiments have extensively searched for **New Physics…**

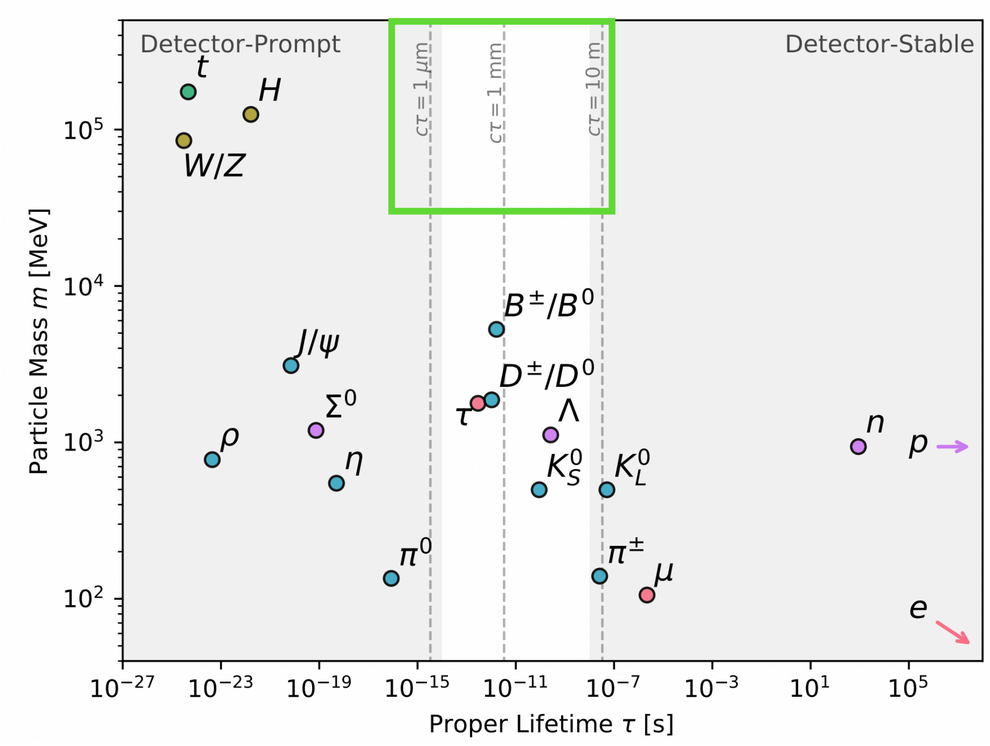
So why haven't we found it yet?

1. It is above the scale accessible by the LHC
2. It is not where we have been looking

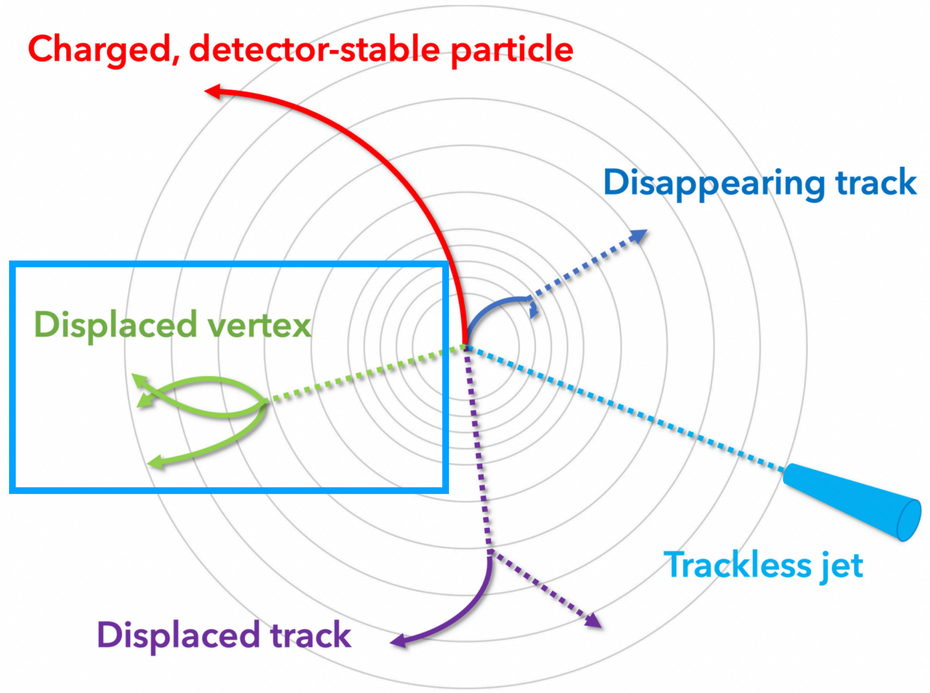
Maybe we have looked in the wrong place?

Long-lived Particles

Long-lived particles (LLPs) could travel **long distances** before decaying to detectable particles, such as leptons.
Various BSM models predicts such **displaced signatures**.

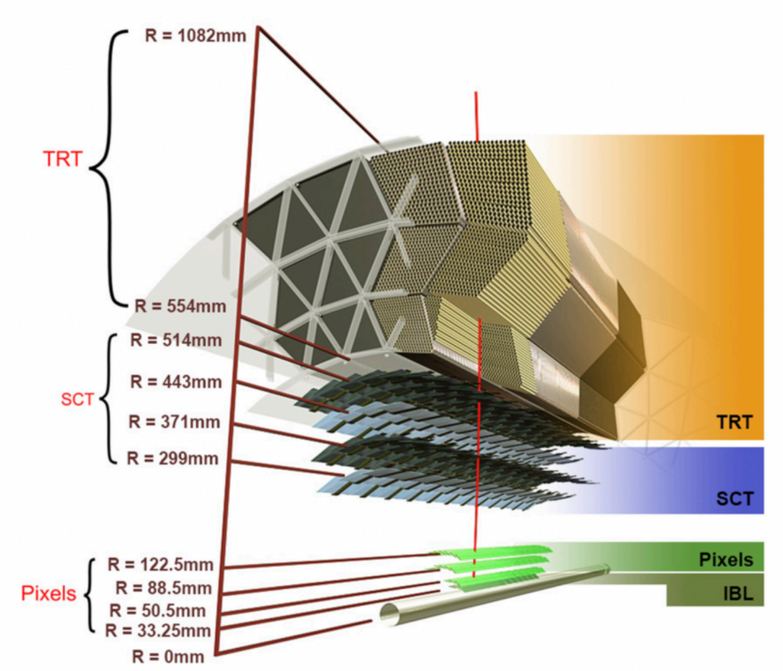


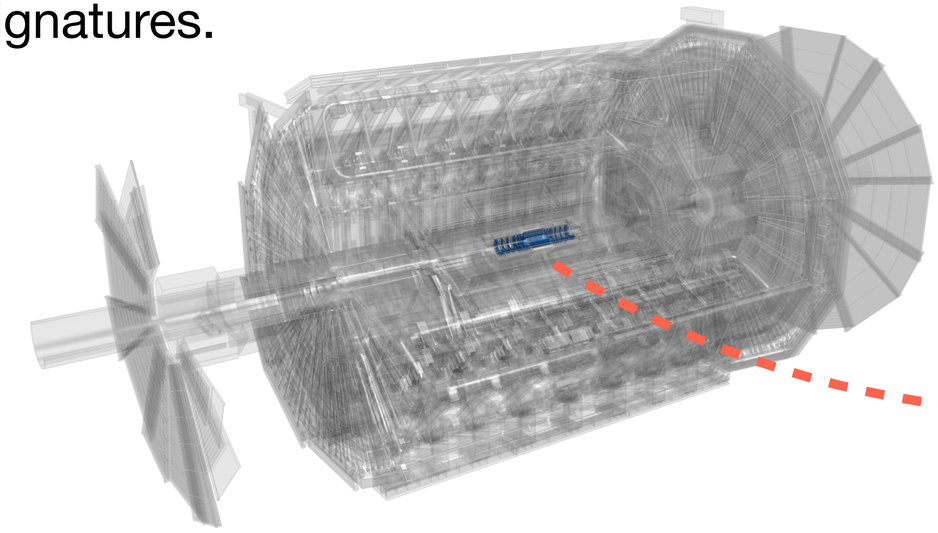
arXiv:1810.12602



Search of LLPs with the ATLAS Detector

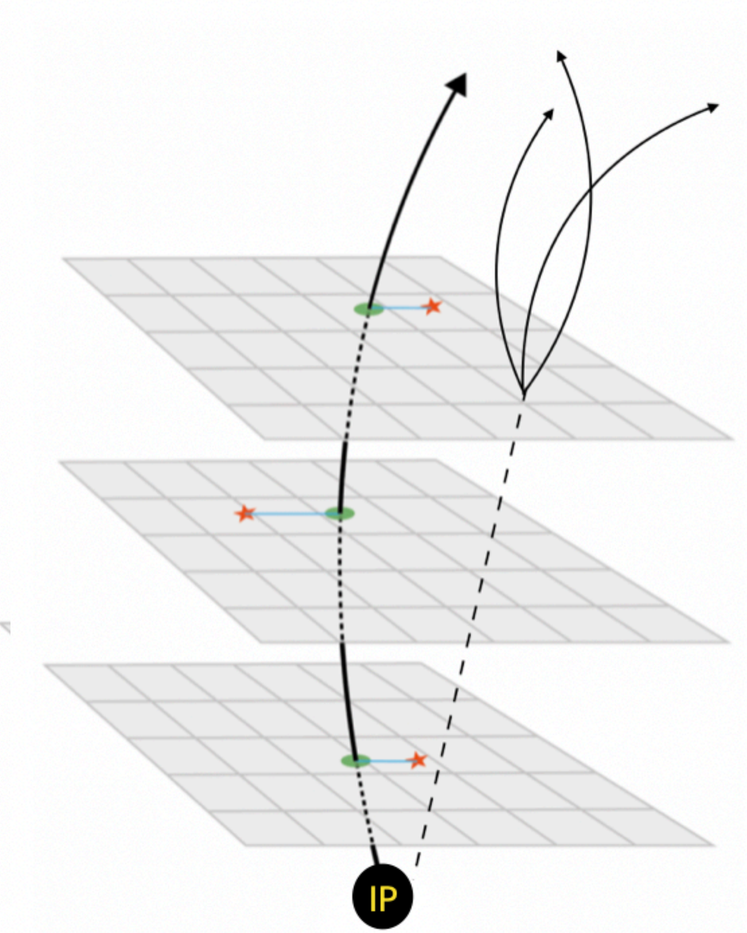
- The **ATLAS** Detector at LHC is a best place to look for the signs of new physics due to the large unexplored phase space and recent crucial improvements to the ATLAS detector performance.
- ATLAS **Inner Detector** (ID) allow us to discover wide range of LLP lifetimes due to exponential nature of particle decay.
- For LLPs search it is essential to reconstruct displaced physics object such as tracks, jets, lepton to increase the **sensitivity** to LLP signatures.





Track reconstruction in the ATLAS Detector

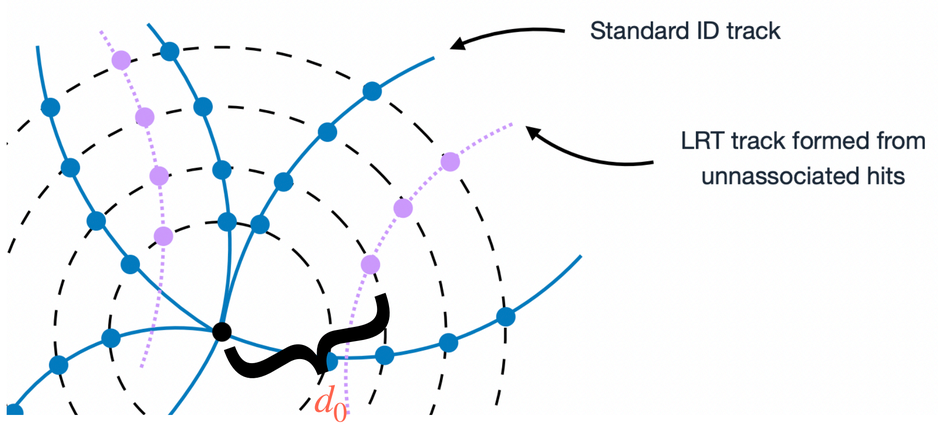
- Tracking reconstructs trajectory of charged particles based on hits deposited on each sub-detectors.
- Tracks are used in almost every reconstructed physics object (Leptons, Primary vertices, Jets etc)
- The standard track reconstruction is optimized for reconstruction of prompt tracks that originate in the vicinity of the Interaction Point (IP).
- To reconstruct displaced tracks (not being produced at the IP) from unconventional signatures, a **special tool** is required.

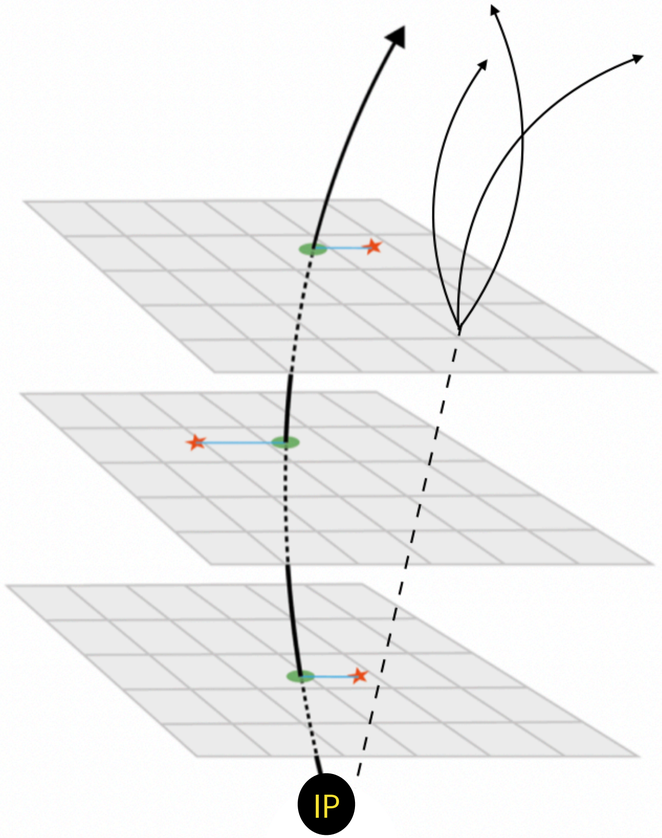


Large Radius Tracking

- Large Radius Tracking (LRT) is a **dedicated track reconstruction algorithm** that utilizes leftovers hits from standard tracking and reconstructs displaced tracks.
- **Standard tracking** constrains the track to originate near the interaction point.
  LRT relaxes these constraints and constructs remaining tracks.
- The **displaced tracks** obtained from LRT algorithm are the main key ingredient in LLPs analysis.

Maximum $|d_0| \rightarrow 300$ mm, $|z_0| \rightarrow 500$ mm





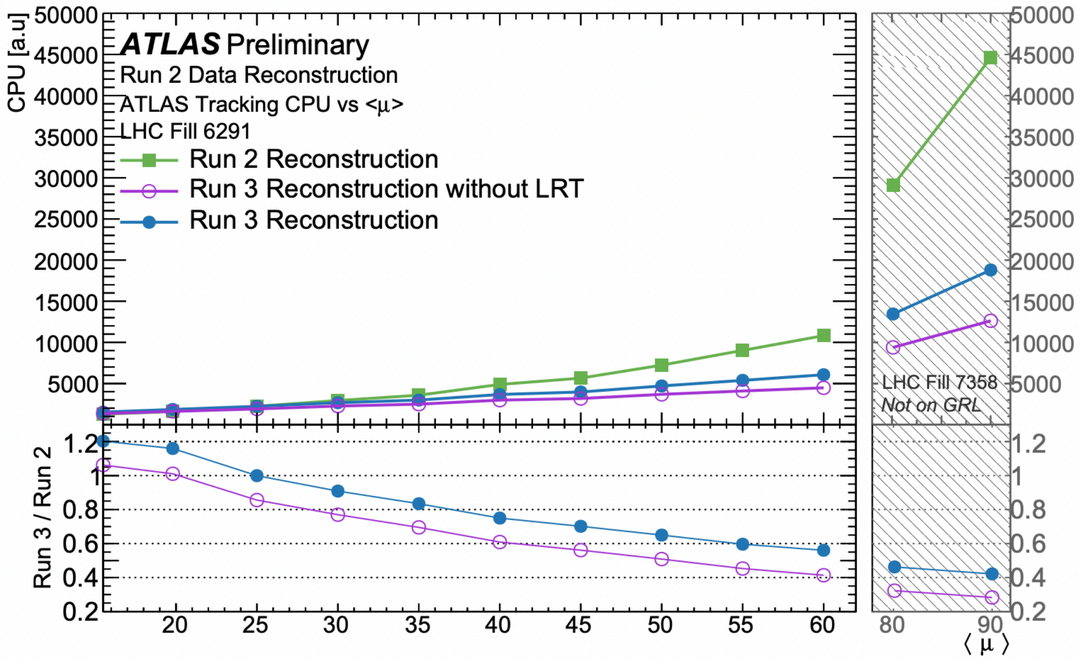
Run-3 LRT Performance

Run-2(2015-2018) LRT was optimized for high efficiency resulting in a large number of fake tracks

- Fake tracks: tracks that do not correspond to any true charged particle trajectories

Run-3(2022-2024) LRT has been **re-optimized**:

- Significant reduction in fake rates (10–15 % reduction in efficiency, 95 % reduction in fakes)
- Significant CPU reduction



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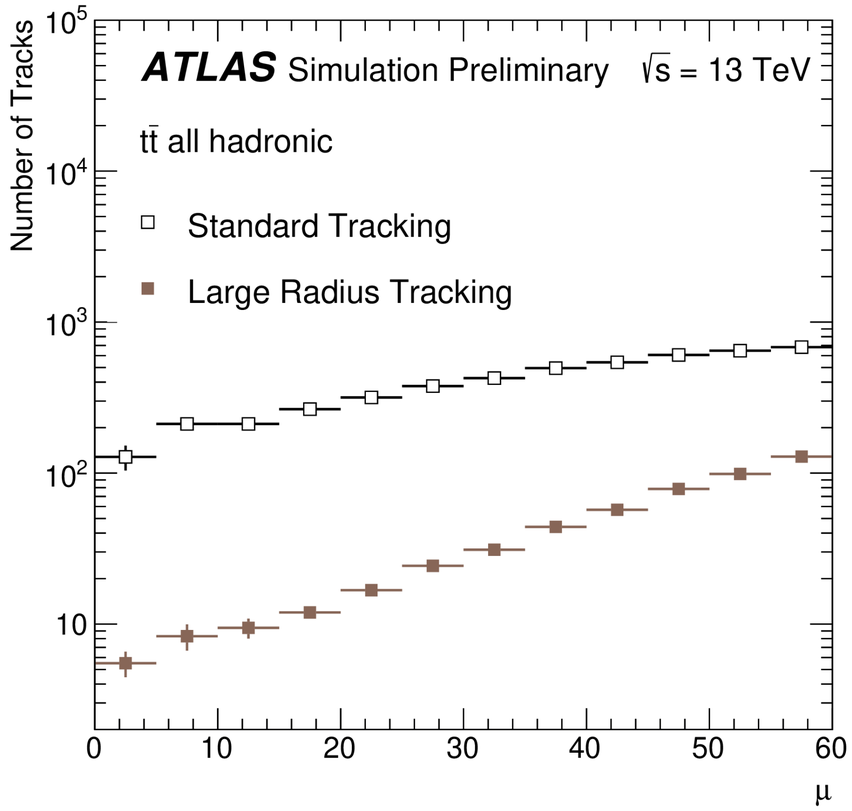
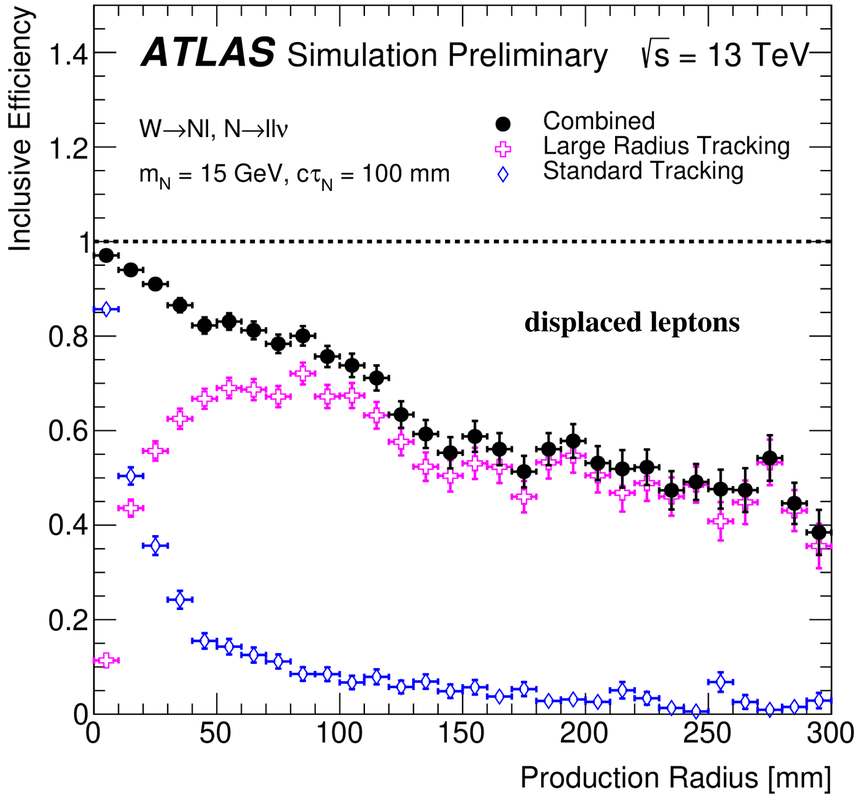
ATL-COM-PHYS-2021-1041 (ATLAS INTERNAL NOTE)

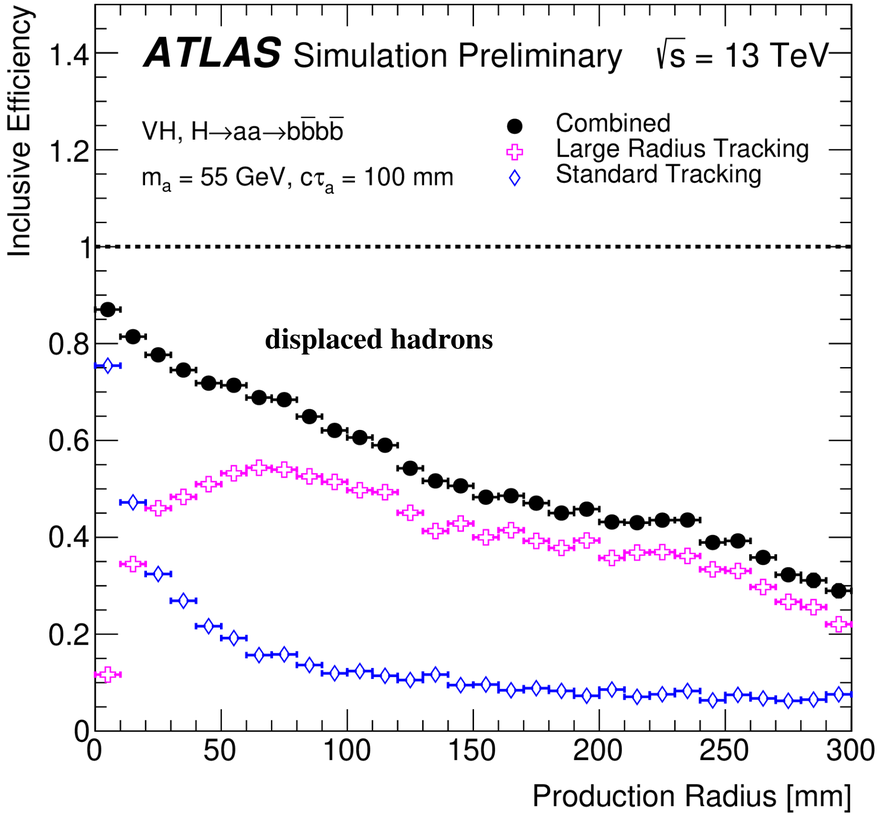


Run-3 LRT Performance

Run-3 LRT is **highly efficient** at large production radius (> 10 mm).

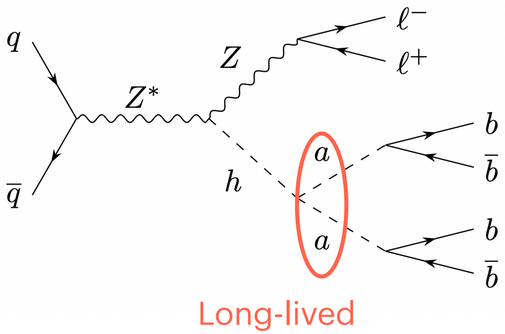
ATL-COM-PHYS-2021-1041 (ATLAS INTERNAL NOTE)



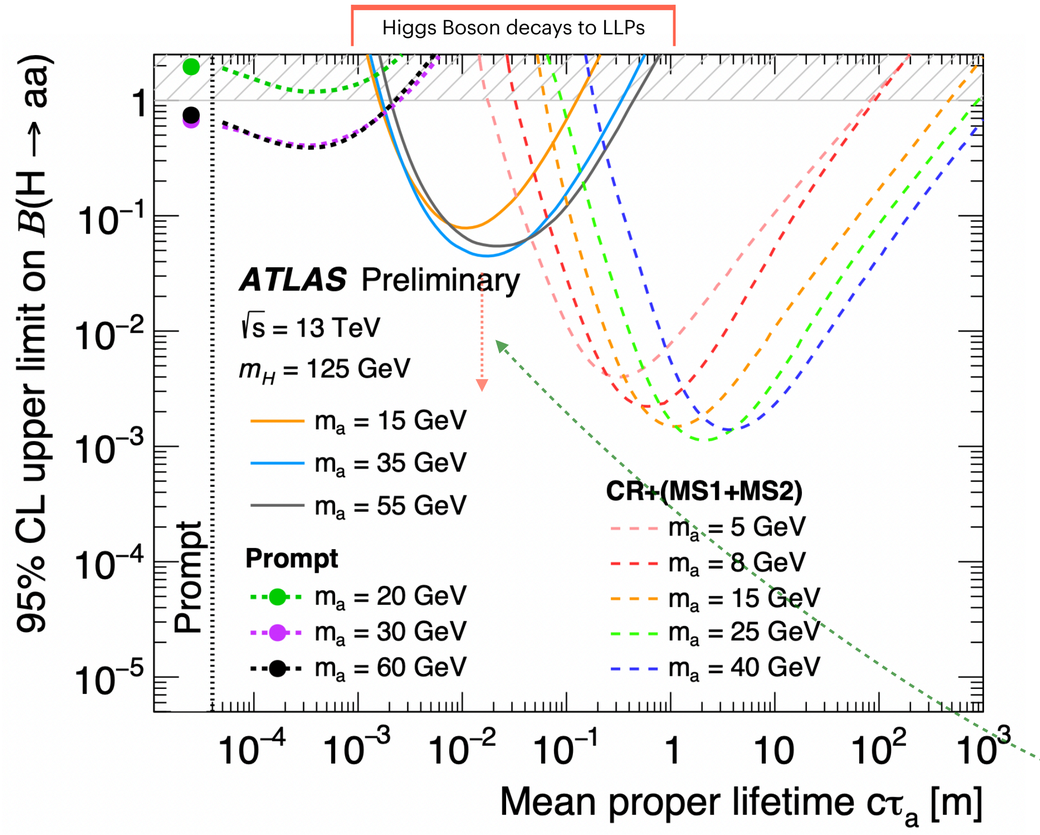


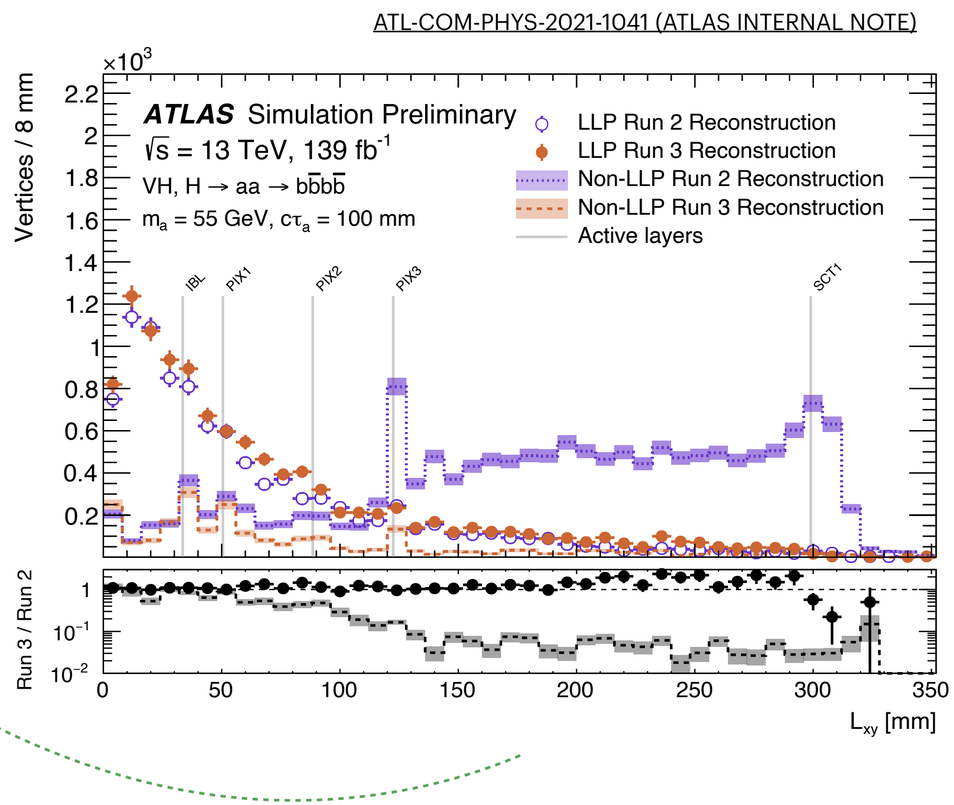
Case Study: Higgs boson decays to LLPs

Analysis uses Run-2 LRT with an additional secondary vertex reconstruction algorithm to reconstruct the decays of the LLPs.



arXiv:2107.06092





With Run-3 LRT we expect at-least factor of 10 improvements in sensitivity due to **reduced number** of background vertices.

Summary

Run 3 LRT implementation will boost the sensitivity of many LLPs searches with the ATLAS Detector due to major improvements

- Significantly speedup
- Increased flexibility
- High efficient in long lived particle searches
- Drastically reducing the fake rate
- Free significant CPU resources from dedicated workflow
- Stable for challenging pile-up regime

Thank you