Improved track reconstruction for prompt and long-lived particles in ATLAS for the LHC Run 3

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On behalf of the ATLAS collaboration
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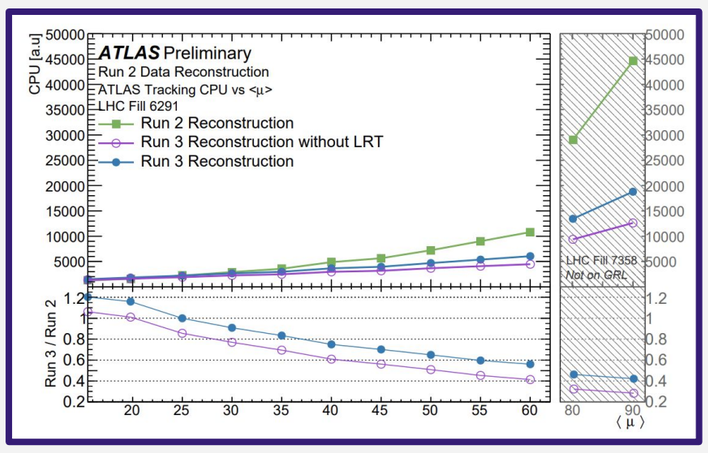
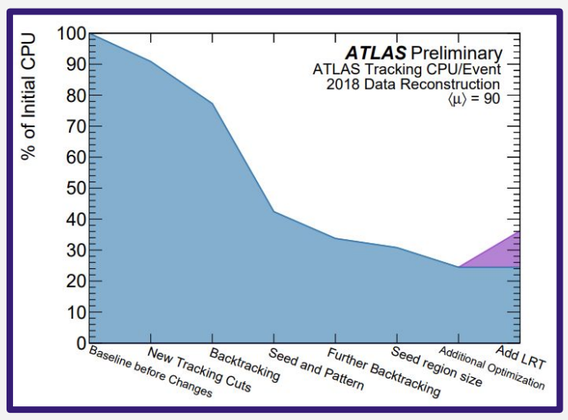
Introduction

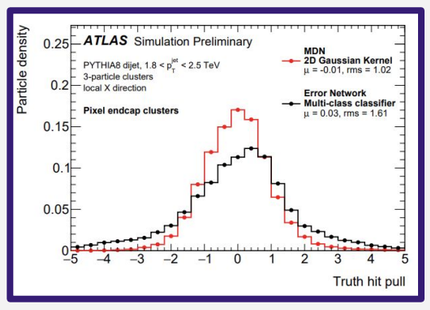
- **Run-3 conditions are particularly challenging** with a high number of simultaneous *p-p* collisions (pile-up,μ) compared to Run-2, with a design value of 60 interactions per bunch crossing.
- Reconstructing charged particle trajectories (tracks) in the Inner Detector is by far the **most resource-intensive** portion of the ATLAS reconstruction chain
- Run-2 track reconstruction **scaled exponentially** with increasing pile-up owing to increased combinatorial complexity
- Large-scale effort to **reduce pile-up dependency,** both in performance and resource, aiming to **abort reconstruction of low-quality tracks at earlier stages**
- Run-3 execution speed **now more than 2x faster** and **scales near-linearly** with increasing pileup

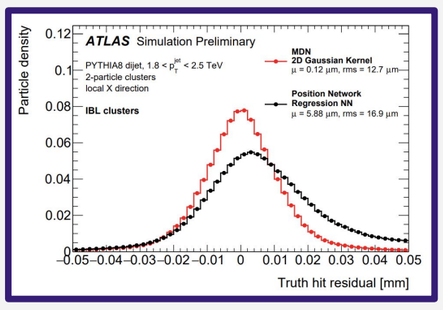




Pixel Cluster Splitting using Mixture Density Networks (MDN)

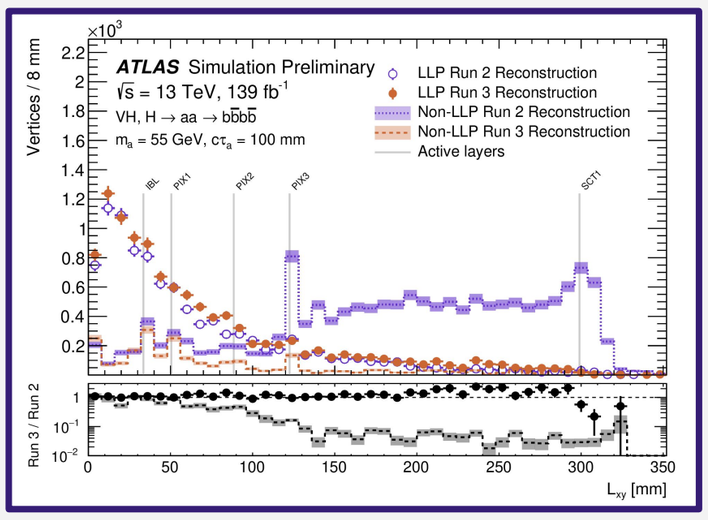
- In Run-2, 10 neural networks (NN) were used to **resolve merged clusters** and **correct cluster positions and uncertainties**
- MDNs can provide an estimate of **position and uncertainty at the same time**, reducing the computational complexity
- Now use three MDNs for Run-3, **improving both computational and physics performance** over original NN approach



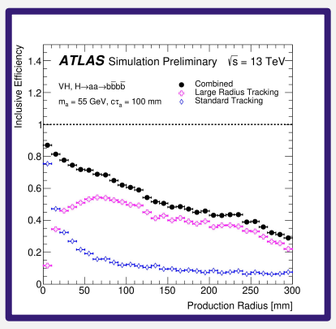


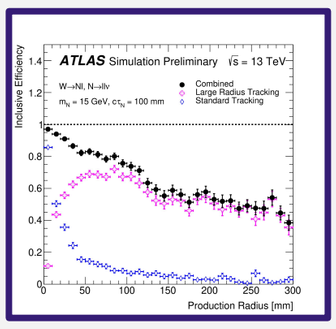
Large Radius Tracking (LRT) Performance

- Standard track reconstruction pass not optimized for **long lived particle** (LLP) searches
- Dedicated "**LRT**" pass uses leftover hits not used in primary reconstruction pass with **loosened requirements** on track d_0 and z_0
- Run 2 implementation computationally limiting and run on only a ~10% subset of total data



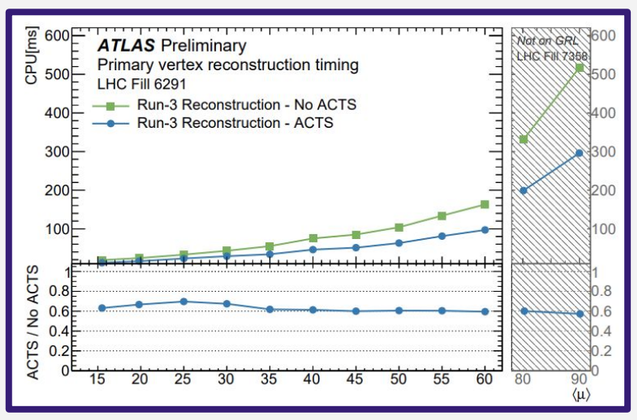
- Run 3 computational time **drastically reduced** while maintaining excellent physics efficiency by tightening selection criteria in key areas
- Due to large performance gains, now **fully integrated into default reconstruction chain**, greatly boosting Run-3 sensitivity for LLP searches

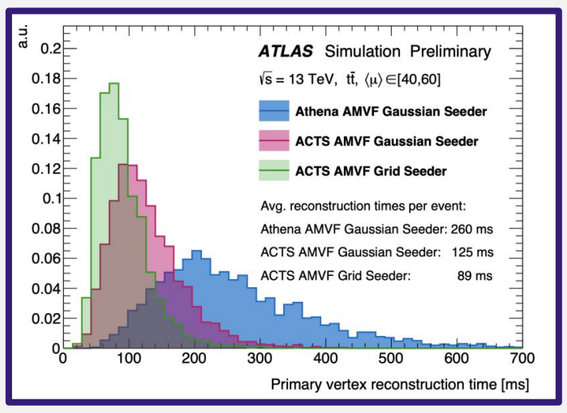




Adaptive Multi Vertex Fitter (AVMF) and ACTS Integration

- Run-2 vertex finding algorithm used **iterative approach** that constructed vertices sequentially, which had more sensitivity to pile-up effects
- An **adaptive multi vertex fitter (AVMF)** algorithm was developed where multiple vertex candidates are allowed to **compete for tracks** to reduce the probability that nearby interactions are reconstructed as a merged vertex, **reducing the pile-up dependency**
- ACTS framework[1] derived from ATLAS track reconstruction to provide to the broader community a detector agnostic toolkit that is **thread-safe and highly optimized**
- ACTS implementation of AVMF algorithm **now used as primary vertex reconstruction in Run-3**





ATL-PHYS-PUB-2021-012, PLOT-IDTR-2021-03, PLOT-IDTR-2021-002, PLOT-IDTR-2021-001

1: *A Common Tracking Software*, arxiv.org/abs/2106.13593