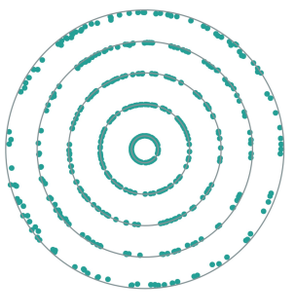
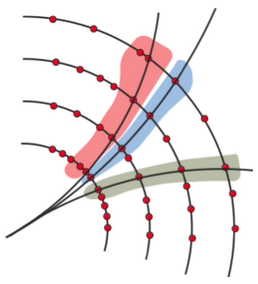
Improved track reconstruction for prompt and long-lived particles in ATLAS for the LHC Run 3

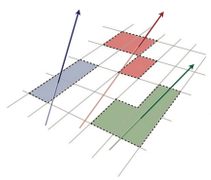
Track reconstruction in the ATLAS Inner Detector (ID)



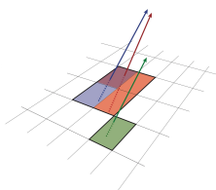
1. pp collision → Charged **particles hit ID sensors**.
2. Signals in adjacent channels grouped together → **Cluster**.



3. Form **track seed** with 3 pixel clusters (one in each layer).
4. Search roads → Kalman Filter algorithm → Associate hits to **tracks**.

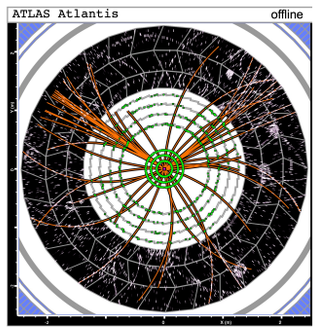


3 charged particles
3 pixel clusters



3 charged particles
1 pixel cluster

5. More than one hit per cluster?
6. Solve ambiguity using Machine Learning → **Hit positions and their uncertainties**.



7. Re-fit of the obtained tracks using **global χ^2** method → **Final tracks**.
8. Look at the **final track position** at their closest point to the **beamline** → Fit to obtain primary vertices (**PV**).

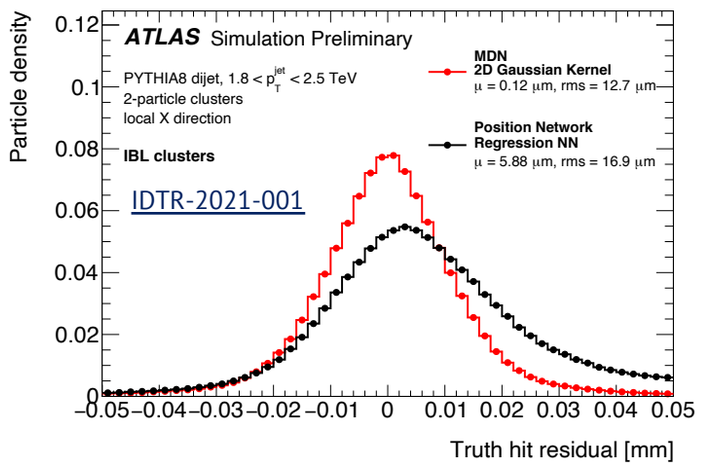
LHC Run 3, what a challenge!

- From Run 2 to Run 3, increase of the number of proton-proton collisions per bunch crossing (pile-up, $\langle\mu\rangle$).
- **Run 2** → $\langle\mu\rangle$ **~ 30**
- **Run 3** → $\langle\mu\rangle$ **~ 50**

Two main challenges in Run 3:

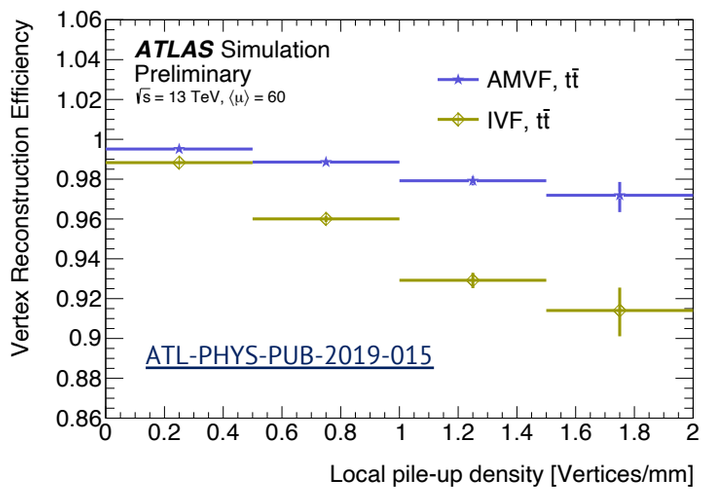
1. **Software**-related → Larger $\langle\mu\rangle$ ⇒ Larger # of hits ⇒ More complex combinatorics for track reconstruction ⇒ **Higher per-event processing time**.
2. **Physics**-related → Larger $\langle\mu\rangle$ ⇒ Larger density of hits ⇒ **Larger density of tracks** ⇒ Need better algorithms e.g. to discriminate merged clusters or to compute PVs.

6. Improved hit position determination: Mixture Density Network (MDN)



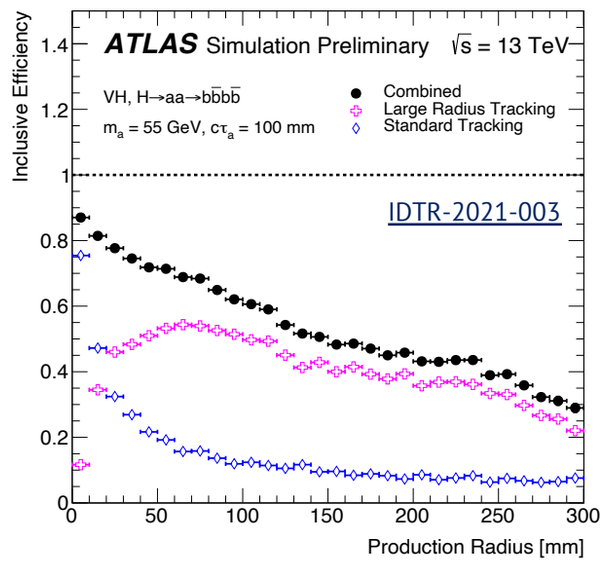
- Precise knowledge of hit position is **essential for high sensitivity to track parameters** e.g. p_T.
- **Run 2** → Several Neural Networks (NN) to predict particle hit position and its uncertainty.
- **Run 3** → One MDN predicts hit position and its uncertainty. Better nominal position and resolution than Run 2 NNs.

8. Improved primary vertex (PV) reconstruction



- Precise determination of PV is **essential to reconstruct the full kinematic** properties of an interaction.
- **Run 2** → Iterative vertex finder (IVF).
- **Run 3** → Adaptative multi-vertex finder (AMVF) . Better reconstruction efficiency than Run 2 IVF.

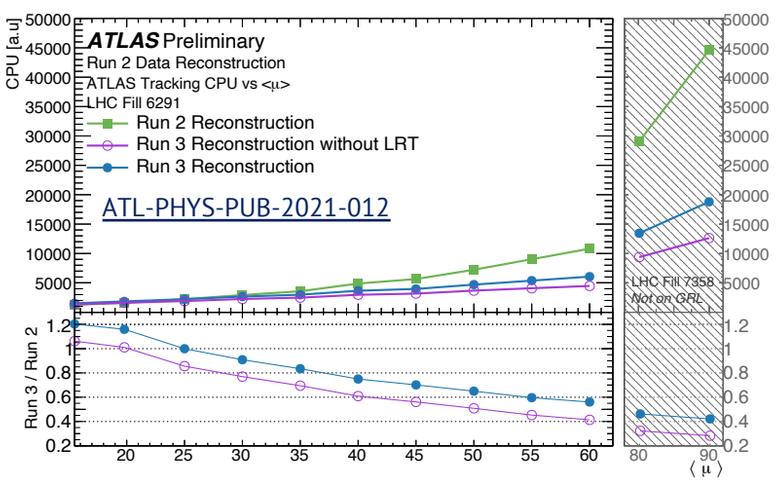
Improved Large-Radius Track (LRT) reconstruction algorithm



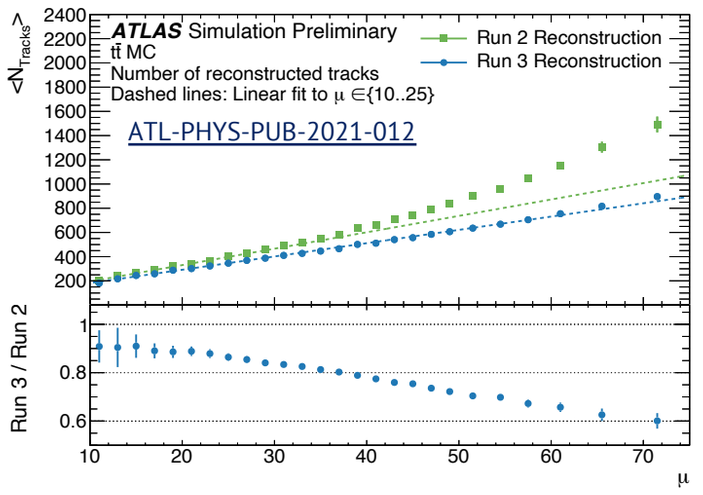
- Standard track reconstruction is optimized for particles produced close to the interaction point (IP).
- Dedicated LRT reconstruction algorithm **crucial for Long-Lived Particle (LLP) searches**.
- **Run 2** → LRT reconstruction optimized for high signal efficiency ⇒ High processing times for real data-taking ⇒ Applied to O(10%) of events.
- **Run 3** → LRT reconstruction was optimized ⇒ Reconstructed in every event.

Consequences for the full track reconstruction chain

Processing time reduction



Better track identification (less fake tracks)



- **Per-event processing time** of the full track reconstruction chain **reduced by a factor** > 2 in high pile-up environments.
- # of **fake tracks** drastically **reduced** at high pile-up.

First proton-proton collisions of LHC Run 3 at $\sqrt{s} = 900$ GeV

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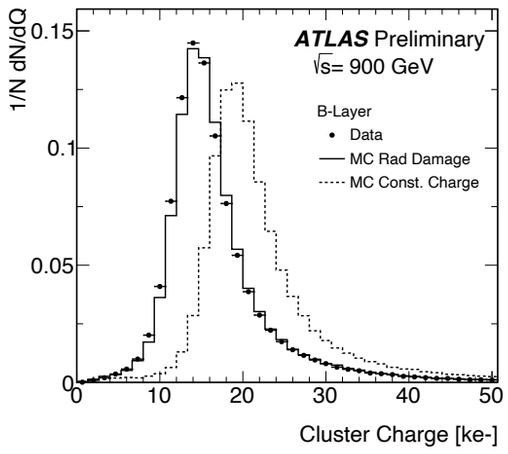

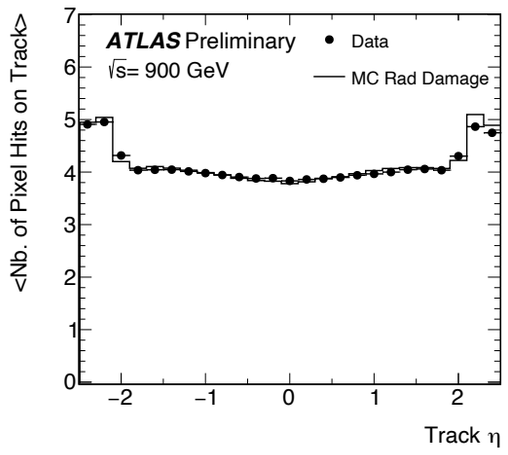

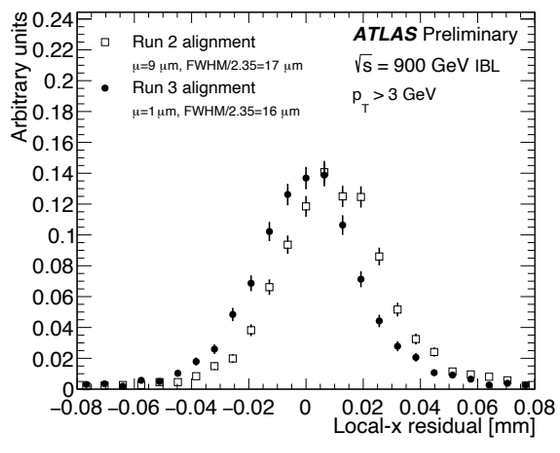

- **Radiation damage** of the pixel sensors was included **in Run 3 simulation**.
- 900 GeV **Data/MonteCarlo** shows **good agreement**.

First alignment of 2022 data-taking!!

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