

# Vertex reconstruction with ATLAS Inner Detector and Inner Tracker

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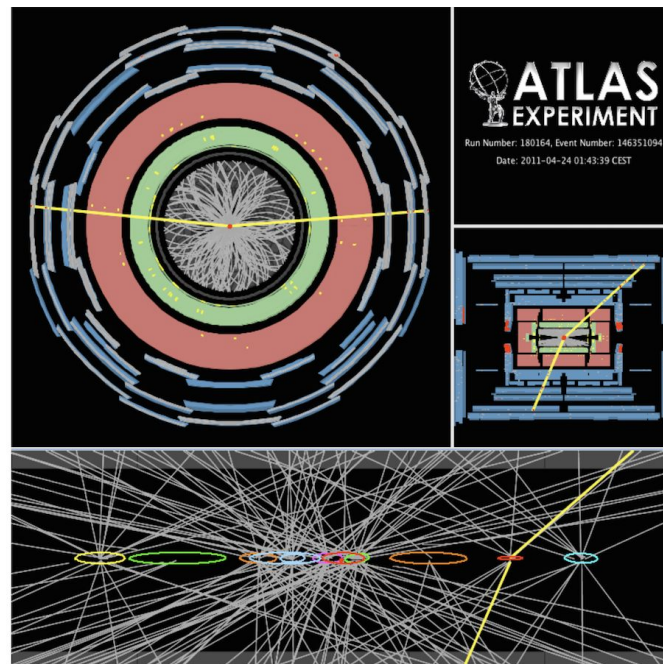
on behalf of ATLAS Collaboration

07/14/2021

DPF2021

# Outline

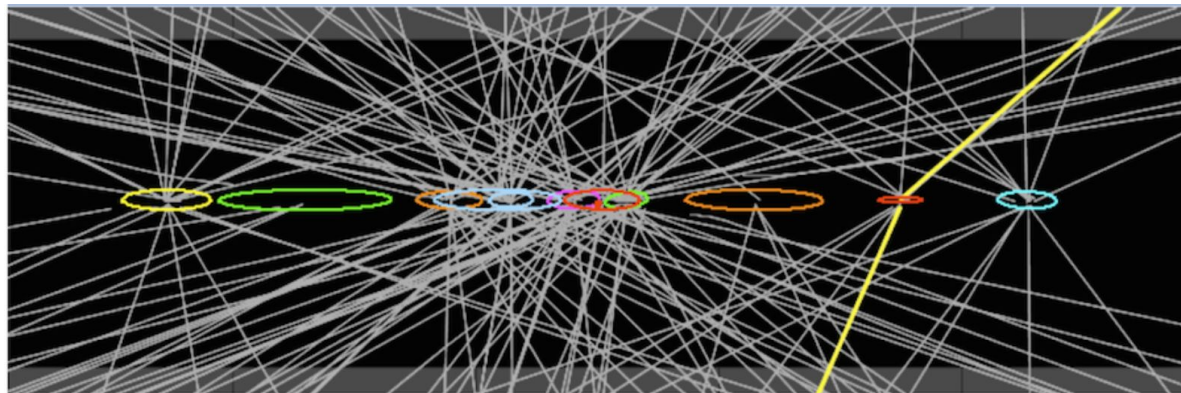
- > **Primary Vertex reconstruction**
  - Adaptive multi-vertex finder (AMVF)
- > **Expected performance with Inner Detector (ID) for Run3**
- > **Expected performance with Inner Tracker (ITk) for Run4**



Event display showing a Z boson decaying into two muons with 11 reconstructed vertices

# ATLAS primary vertex reconstruction

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- > Multiple proton-proton collisions per beam crossing
  - ~60 at Run2, ~200 at Run4
- > Primary vertex reconstruction
  - Seed finding
  - Track assignment
  - Fitting



# Seed finding

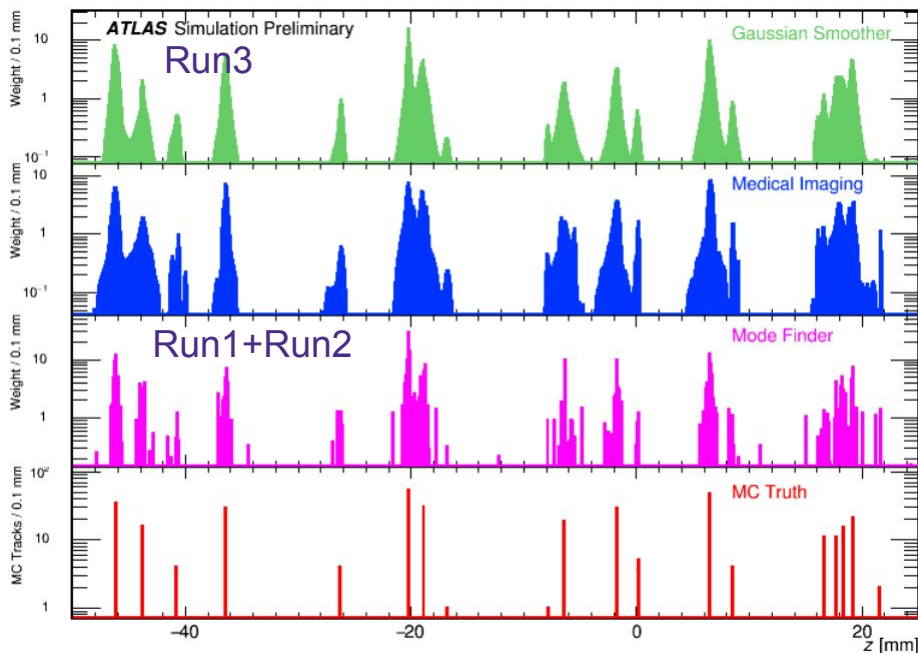
- Input: reconstructed tracks passing a quality selection
- Output: Vertex candidate
- Two new approaches are studied
  - Medical imaging
  - Gaussian seed finder

Track's seed-finding density

$$P(r, z) = \frac{1}{2\pi\sqrt{|\Sigma|}} e^{-\frac{1}{2}((r-d_0), (z-z_0))^T \Sigma^{-1} ((r-d_0), (z-z_0))}.$$

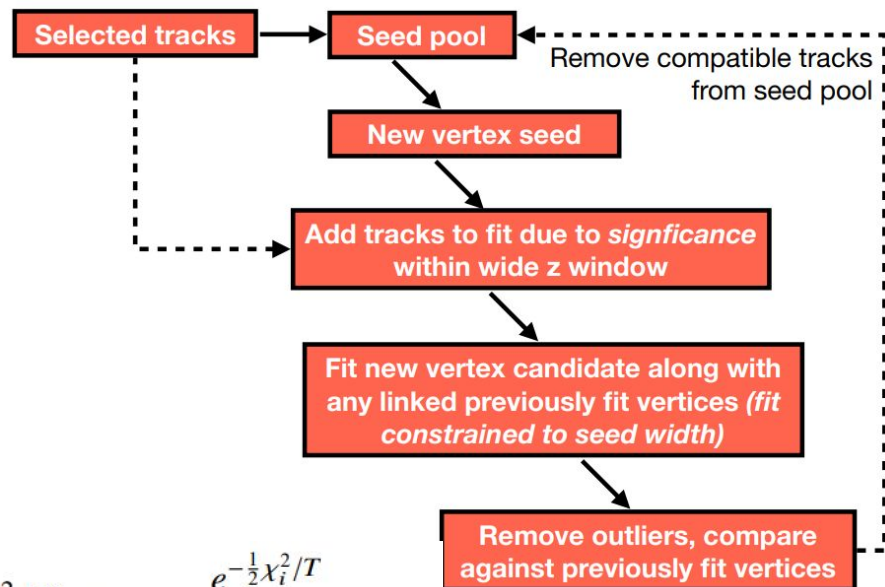
Total density - sum of all tracks ( $r > 0$ )

$$W(z) = \sum_{i \in \text{tracks}} P_i(0, z). \quad \text{Peak search: } W'(z) = 0$$



# Adaptive Multi-Vertex Finder (AMVF)

- > Allows tracks to have weight in the fits of multi-vertex
- > Gaussian seed finding:
  - tracks not yet assigned to any vertex
- > Track to seed assignment:
  - Nearby tracks to the seed
  - Including the tracks already assigned to other vertex
- > Fitting
  - Weighted adaptive Kalman filter
  - With beam spot constraint

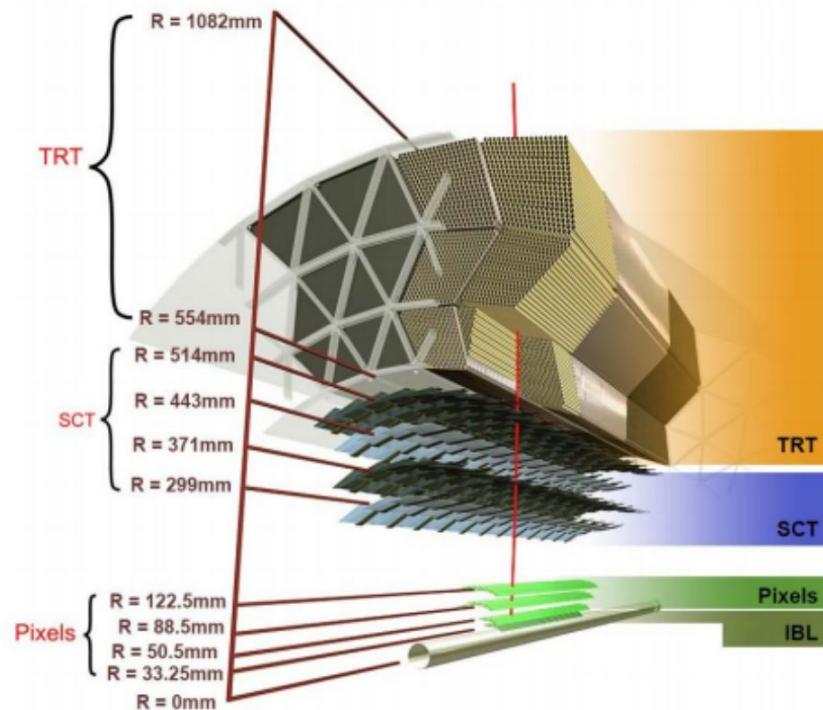


$$\omega_i(\chi_i^2, T) = \frac{e^{-\frac{1}{2}\chi_i^2/T}}{\sum_j e^{-\frac{1}{2}\chi_j^2/T} + e^{-\frac{1}{2}\chi_0^2/T}}$$



# ATLAS Inner Detector (ID)

- > Primary vertex reconstruction relies on charged tracks measured in 3 sub-detectors
- > Pixel detector
  - 4 barrel layers + 3 end-cap layers
- > Silicon Strip tracker (SCT)
  - 4 double sided barrel layers
  - 9 end-cap layers
- > Transition radiation tracker (TRT)
  - 73 barrel planes
  - 160 end-cap planes



# Primary vertex reconstruction performance

Match



Fake



Merge



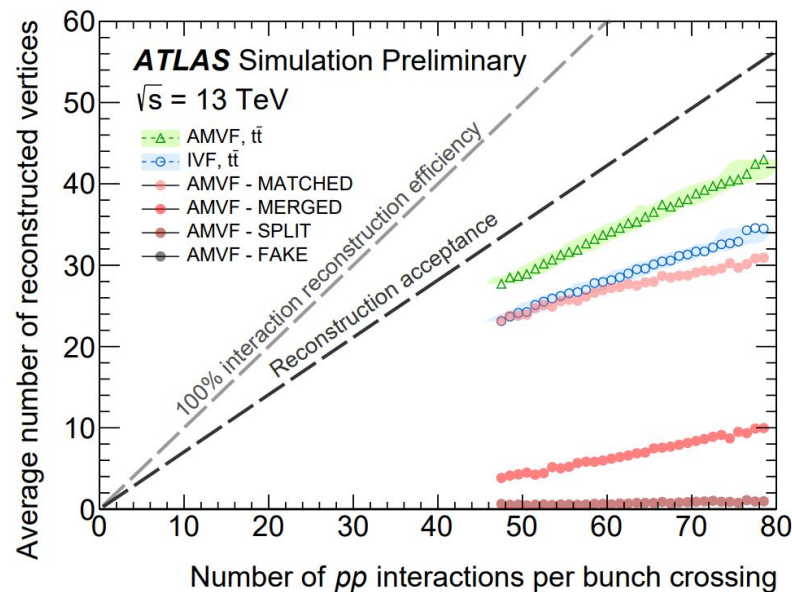
Split



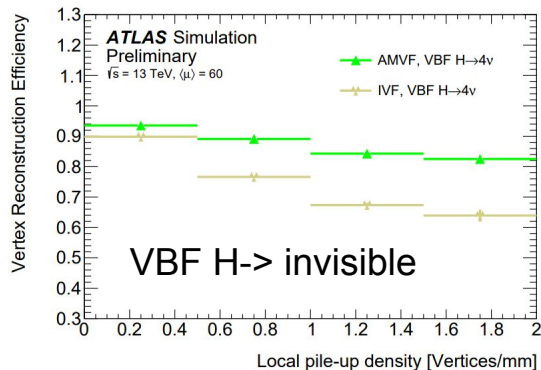
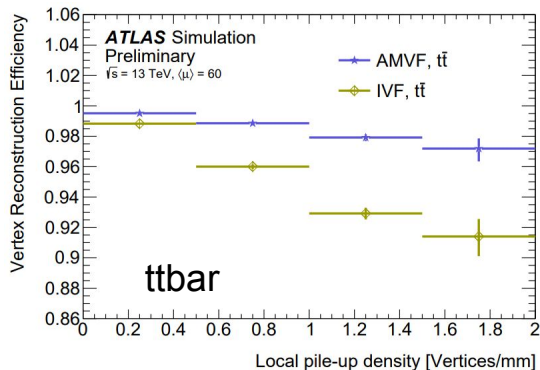
● Generated vertex

● Reconstructed vertex

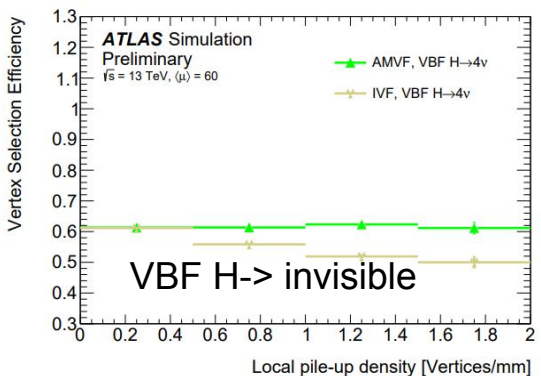
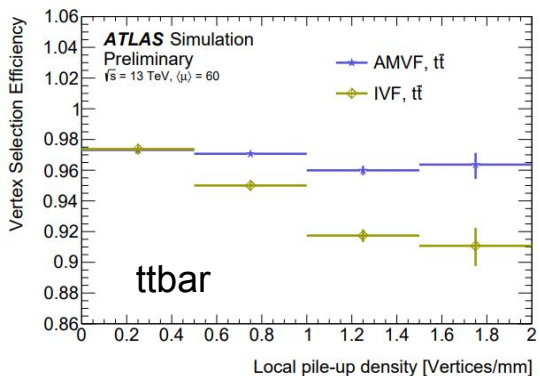
- > AMVF recovers 35-50% of the reconstructable primary vertices lost by the previous method (IVF)



# Hard-Scatter (HS) vertex efficiencies



HS vertex reconstruction efficiency  
More details in [ATL-COM-PHYS-2019-158](#)

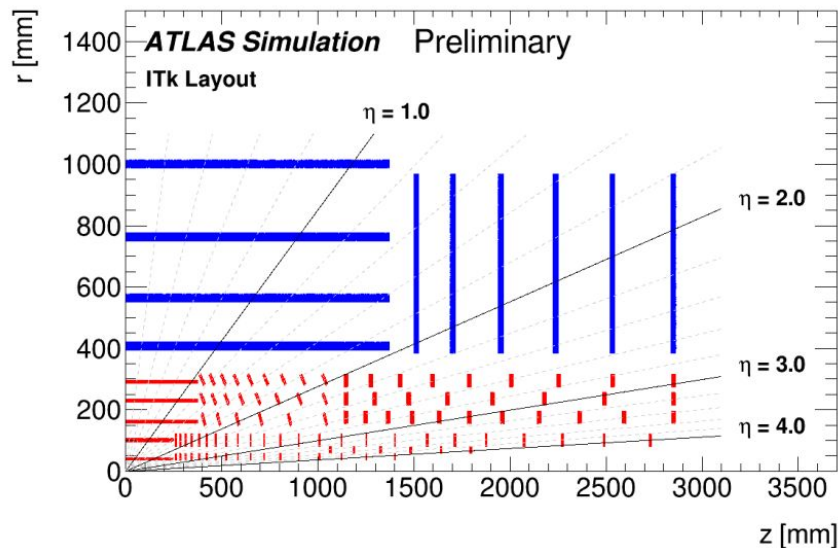


HS vertex selection efficiency  
Selection: highest  $\sum P_T^2$

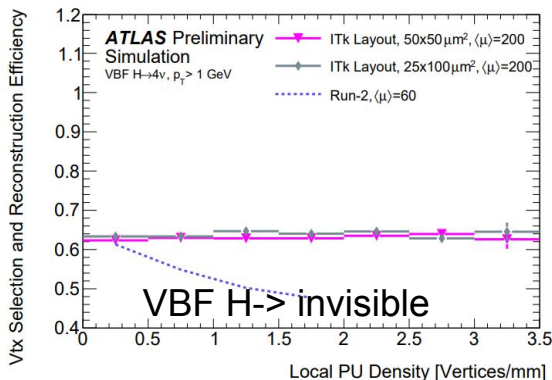
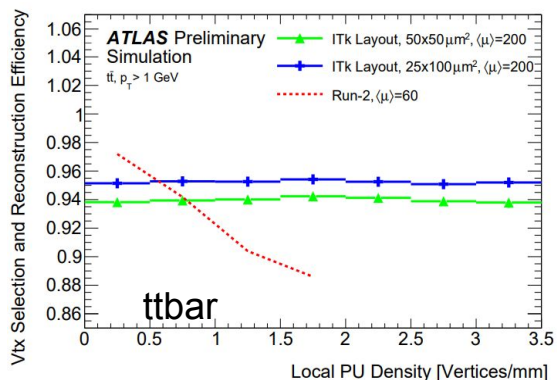
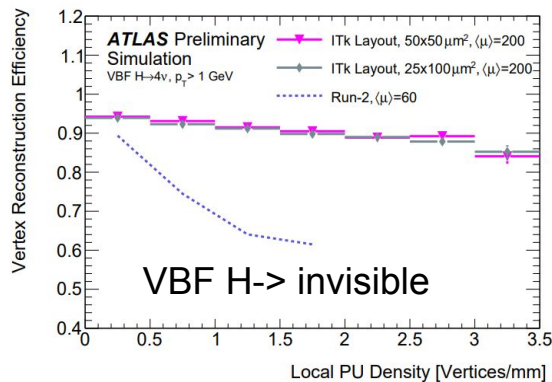
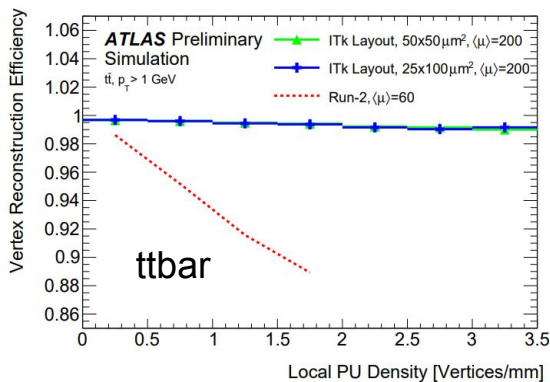


# ATLAS Inner Tracker (ITk)

- > For Phase II upgrade
- > An all-silicon detector consisting of:
  - Pixel sub-detector ( $|\eta| < 4.0$ )
    - > 5 barrel layers
    - > 5 inclined/vertical rings
  - Strip sub-detector ( $|\eta| < 2.7$ )
    - > 4 barrel layers
    - > 6 end-cap rings
- > Nominal pixel pitch of  $50 \times 50 \mu\text{m}^2$  and innermost barrel layer radius 39 mm
  - Alternative:  $25 \times 100 \mu\text{m}^2$
- > Tracking reconstruction efficiency improved in  $|\eta| > 1$



# HS vertex efficiencies



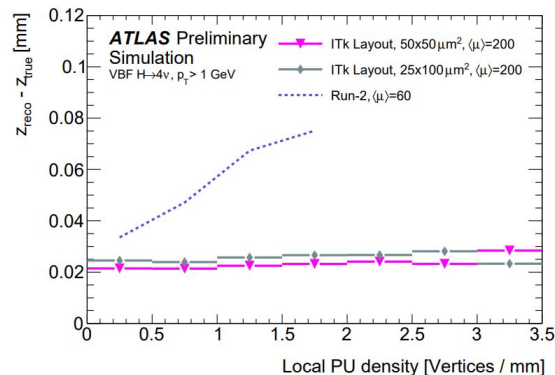
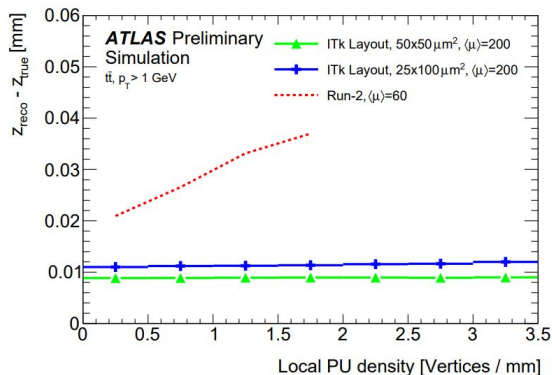
**HS vertex reconstruction efficiency**  
**More details in**  
[ATL-PHYS-PUB-2019-014](#)

**Significant improvement w.r.t. ID**

**HS vertex reconstruction and selection efficiency**



# HS vertex longitudinal resolution



- > Resolution is expected to improve significantly w.r.t. ID
  - Especially at high pile-up condition
- > Slightly better resolution from  $50 \times 50 \mu\text{m}^2$  pixel pitch



# Summary and outlook

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- > Many updates on vertex reconstruction in ATLAS for Run3
  - Gaussian density seed finding
  - AMVF
- > Better performance is expected w.r.t. Run2
  - HS vertex reconstruction/selection efficiency
  - Longitudinal position resolution
- > ITk will replace current ID for HL-LHC
  - Performance improved significantly compared to ID
- > More optimization and evolution are ongoing to further improve performance

