

# Parameterisations of the upgraded ATLAS detector performance at the HL-LHC

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on behalf of the ATLAS Collaboration*



# Overview

## Physics Objects

Jets

Missing transverse energy

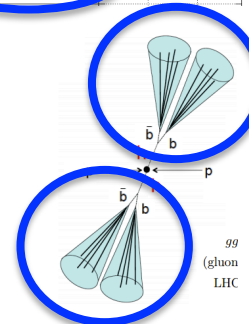
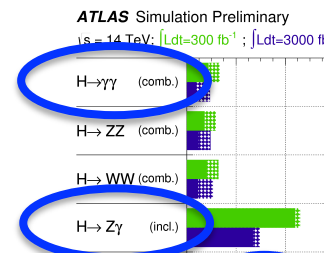
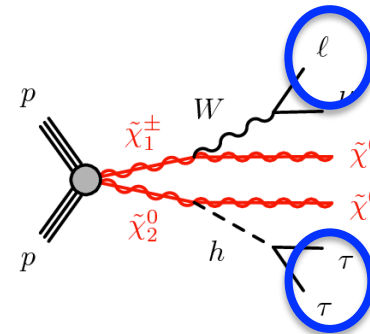
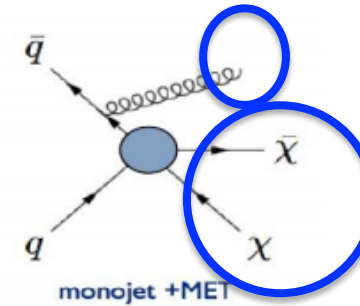
Leptons

Taus

Photons

b-jets

Performance  
Efficiency  
Fake-rates  
Resolution



## Estimating reconstruction performance

- Physic objects
- HL-LHC configuration
- Updated ATLAS detector
- Parameterisations

## Latest performance studies

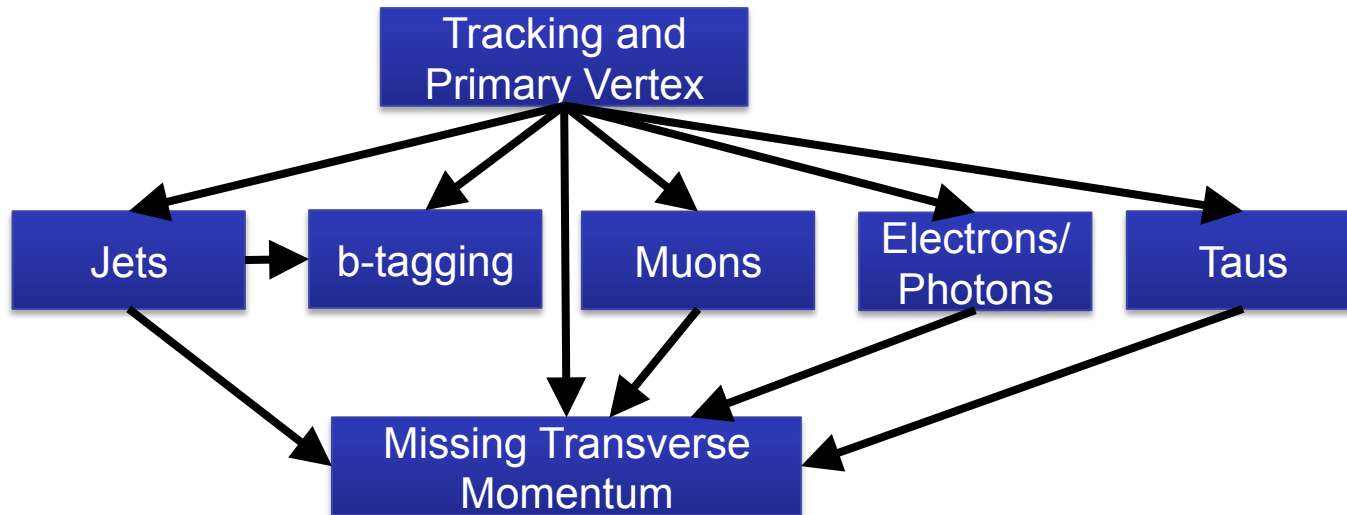
- Overview
- Tracking and muons
- Primary vertexing
- b-tagging

## Summary and Plans

Vital input to HL-LHC physics projections

# Physic Objects

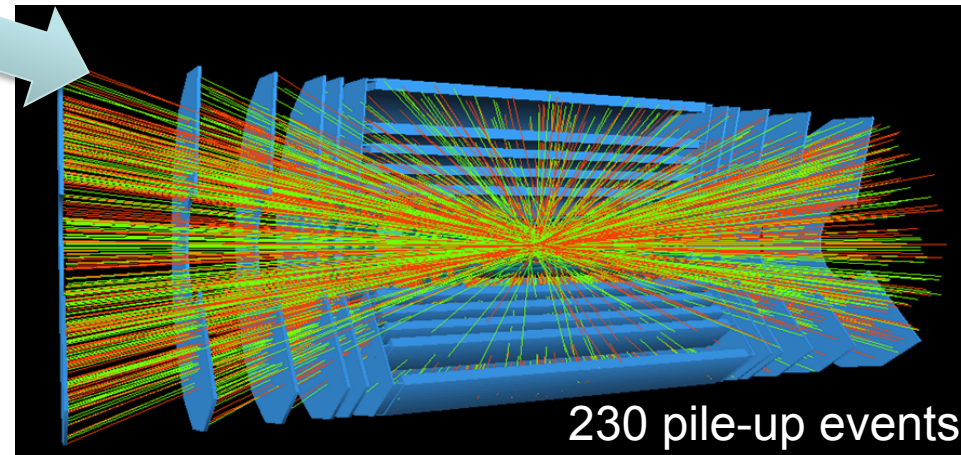
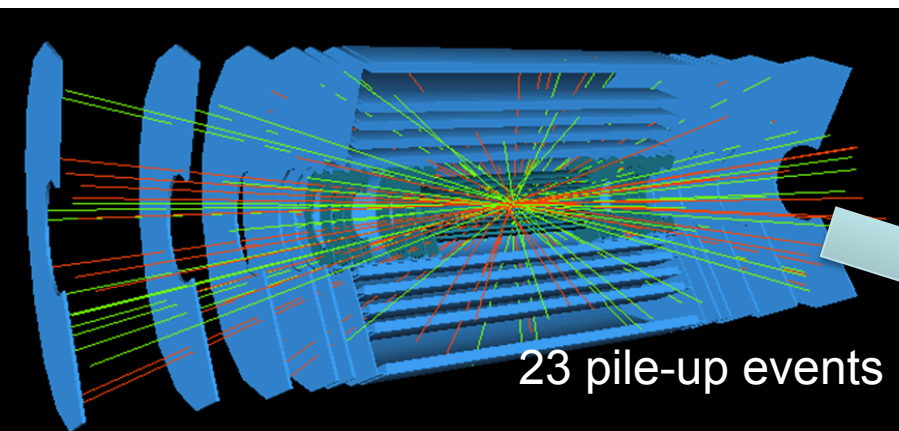
- Several physics objects of interest
  - Reconstructed using complicated and interconnected algorithms
  - Tracking is central to all objects



- When evaluating performance important to consider
  - LHC collision scenarios (pile-up, longitudinal beam spot shape)
  - Detector designs and impact of radiation damage
  - Tuning of algorithms

# HL-LHC Configuration

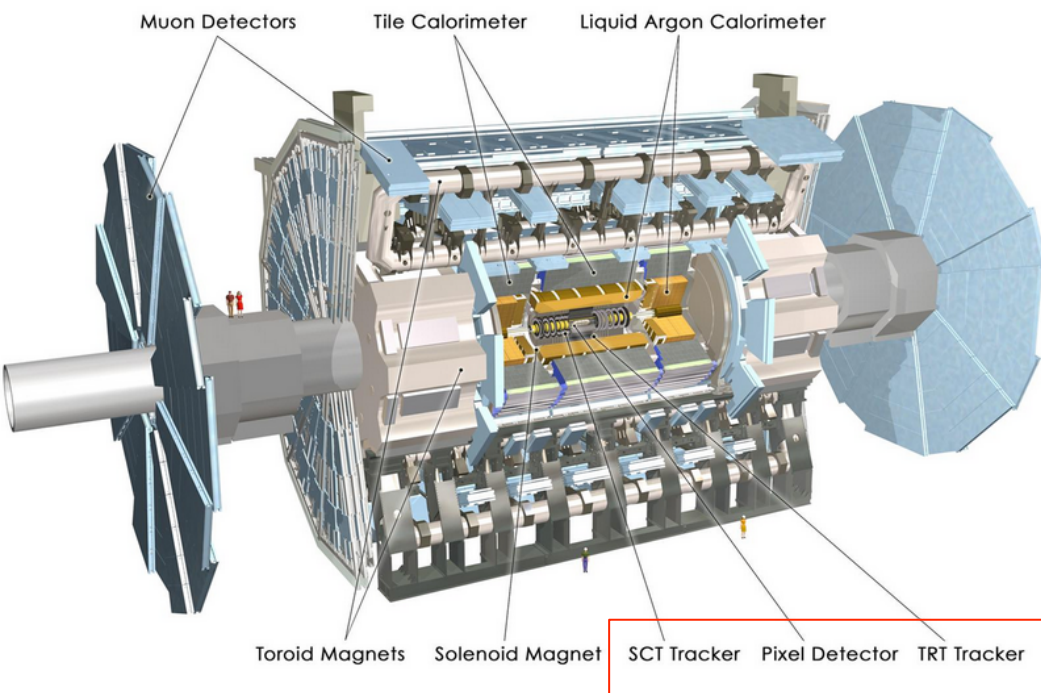
- Very different collision environment compared to Run 1/2
  - Luminosity of  $5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$  corresponds to average of 140 pile-up events
    - To reach 3000  $\text{fb}^{-1}$  a luminosity of  $7.5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$  maybe needed
      - Pile-up of 200 events (also consider 250 or 300)
    - Different longitudinal beam spot shapes: long-flat vs Gaussian
  - Important to consider difference scenarios in performance estimates



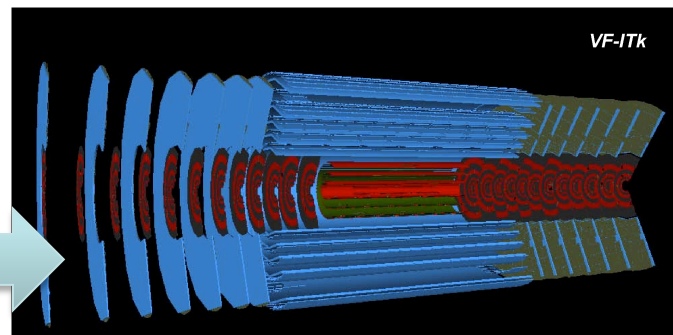


# Upgraded ATLAS Detector

- Essential to upgrade ATLAS
  - Mitigate radiation damage
  - Cope with higher pile-up
  - Maintain or improve performance

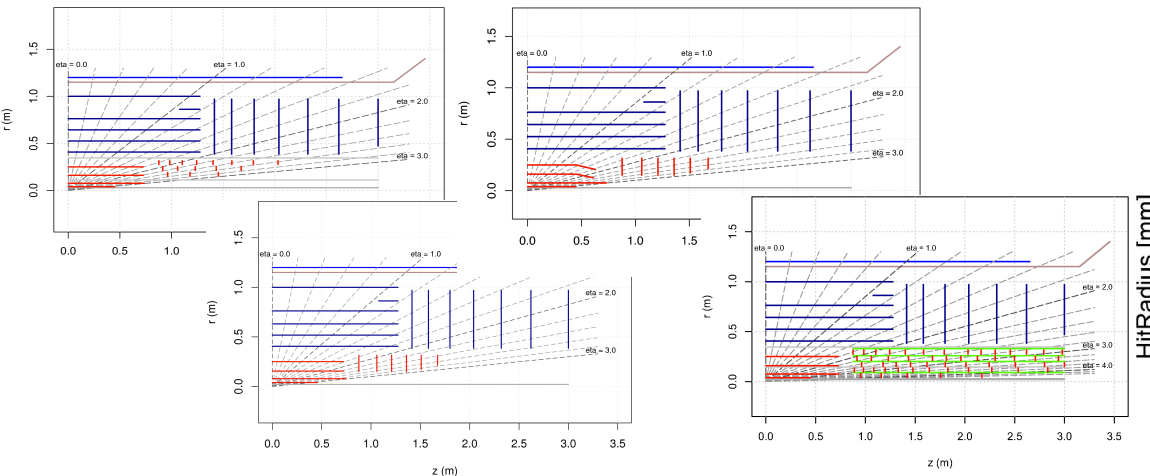


- Main upgrades towards HL-LHC
  - Read-out electronics and DAQ
  - Updated trigger system
    - Finer granularity
    - Two hardware trigger levels (L0\L1)
    - Tracking in lower level trigger
  - New forward muon detectors
  - **New inner tracking detector**

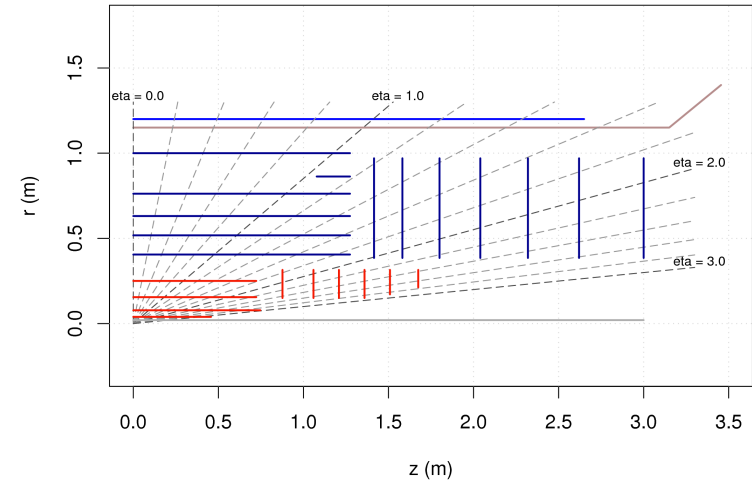


# Upgraded Tracking Detector

- New tracking detector (ITK)
  - All silicon detector with greater granularity
- Configuration still being explored
  - Study **cost** versus **physics output**
  - Described in 'Scoping document' (SD)
    - Released later this year

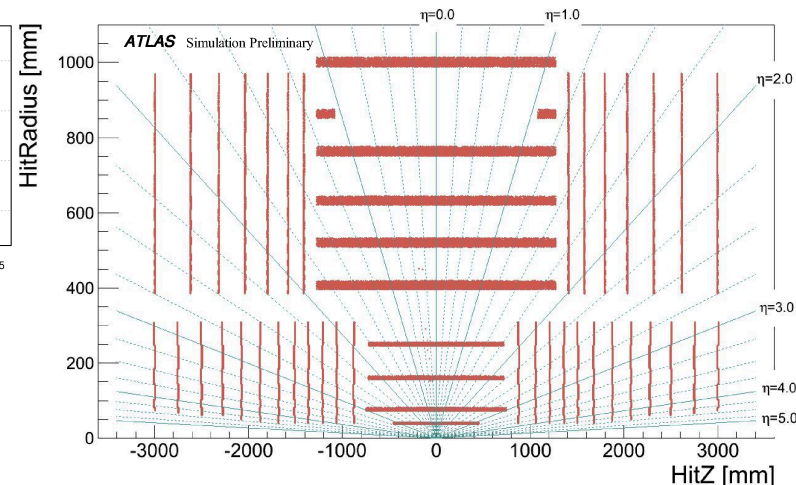


Letter of Intent (LoI) Layout



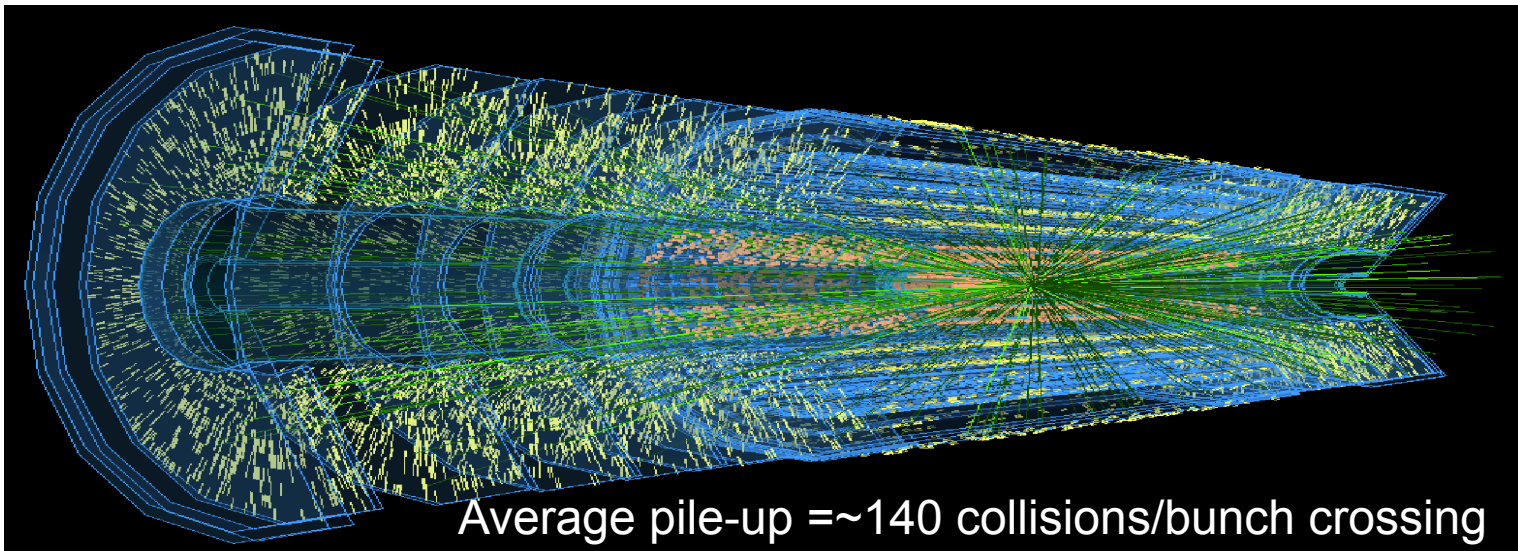
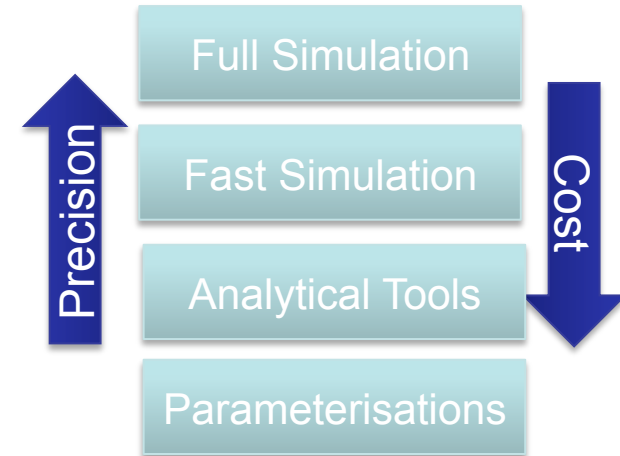
LoI-Very Forward (LoI-VF) Layout

- Caveats
  - Performance will vary as engineering constraints incorporated



# Parameterisations

- Study different layouts, collision schemes and algorithm tunes
  - Need to quickly/easily test in physics studies
- Produce fully simulated/reconstructed events?
  - Extremely costly in terms of CPU and time
- Provide parameterisations of performance
  - Measured on fully simulated events
    - ITK + Run 1 calorimeter/muon systems
  - Smear/correct truth level samples
  - Can also be used externally to ATLAS

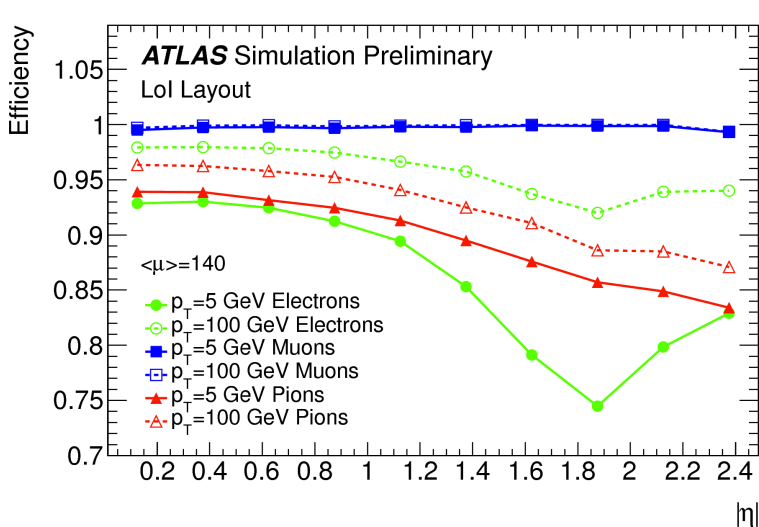


# Status of Studies

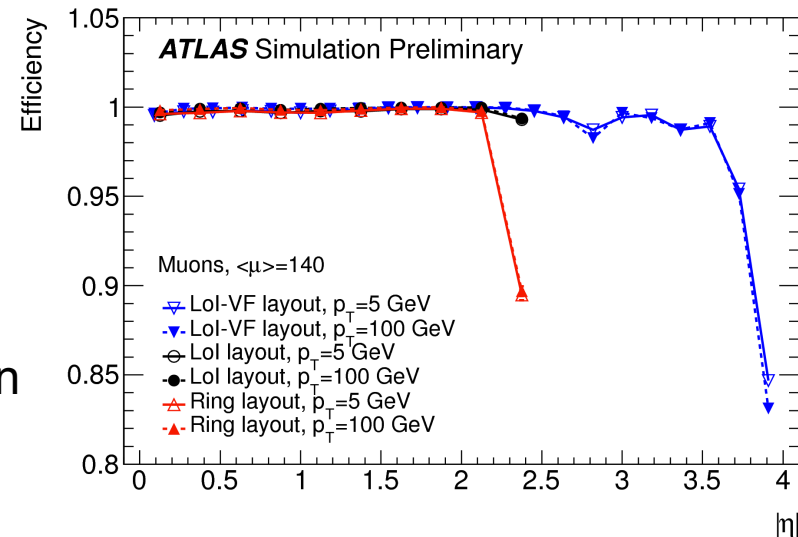
- Performance parameterisations provided for ECFA 2013 conference
  - See [ATL-PHYS-PUB-2013-009](#)
- Updates for the scoping document
  - Jets/Missing energy - many studies with more sophisticated tools
    - See Richard's [talk](#) on Monday
  - Trigger – assume will perform as well or better than Run 1
    - More detailed studies underway
  - Electrons/Photons/Taus – photons updated for ECFA 2013
    - Underway: updated efficiencies, resolutions, extended to forward region
  - **Muons** – smearing/efficiency functions available
    - Underway: updated trigger, all ITK layouts, forward region
  - Tracking: **Tracks**, **primary vertexing** and **b-tagging**
- Overview of latest studies
  - Varying pile-up levels, longitudinal beam spot shape, layouts

# Tracks and Muons

- Tracking performance studies
  - Different ITK layouts, pile-up=140
  - Efficiency, fake-rate and resolution
- ITK provides excellent tracking performance
  - Comparable to performance in Run 1 with 20 pile-up interactions
  - Performance estimate in forward region



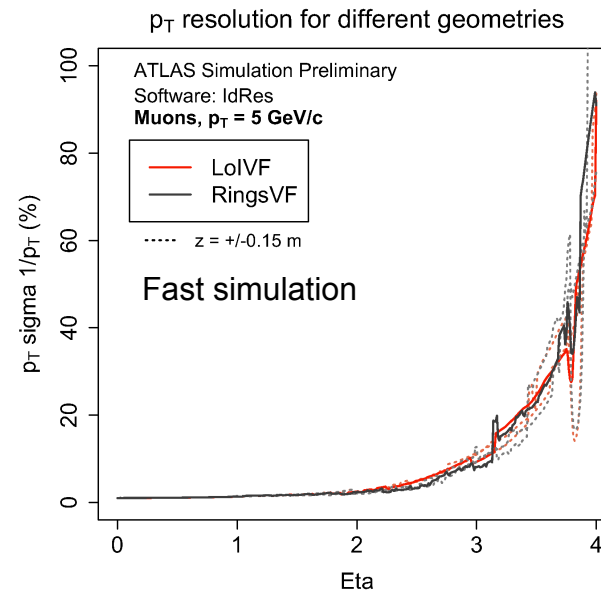
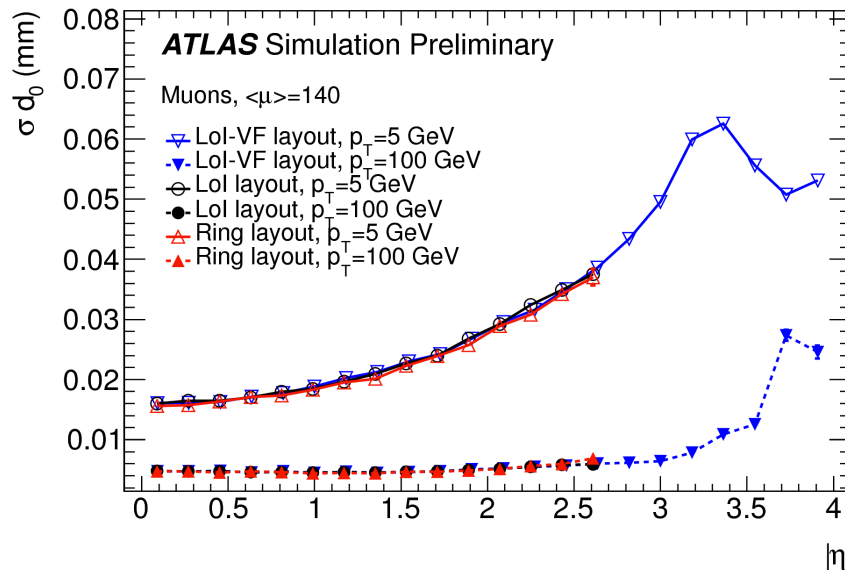
Extend to  
forward region





# Tracks and Muons

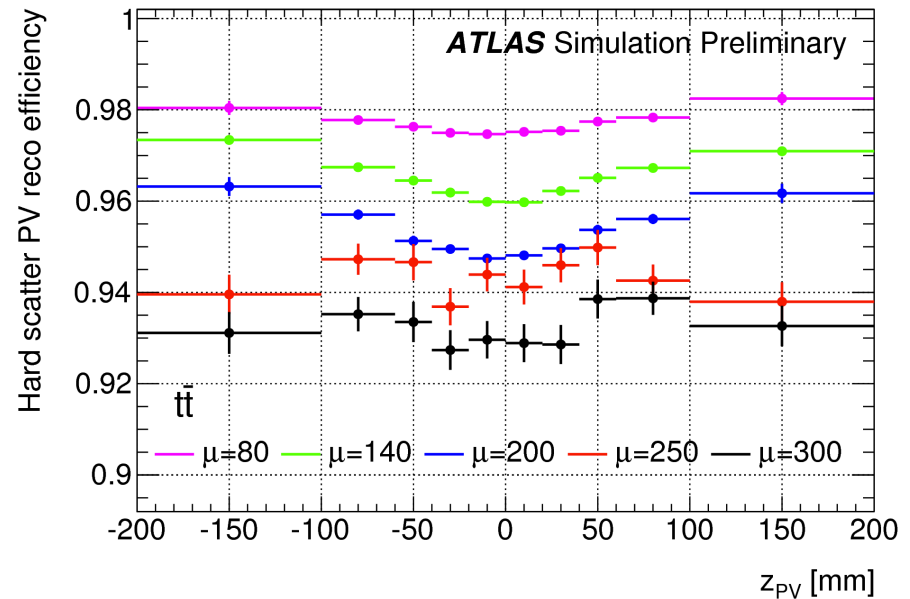
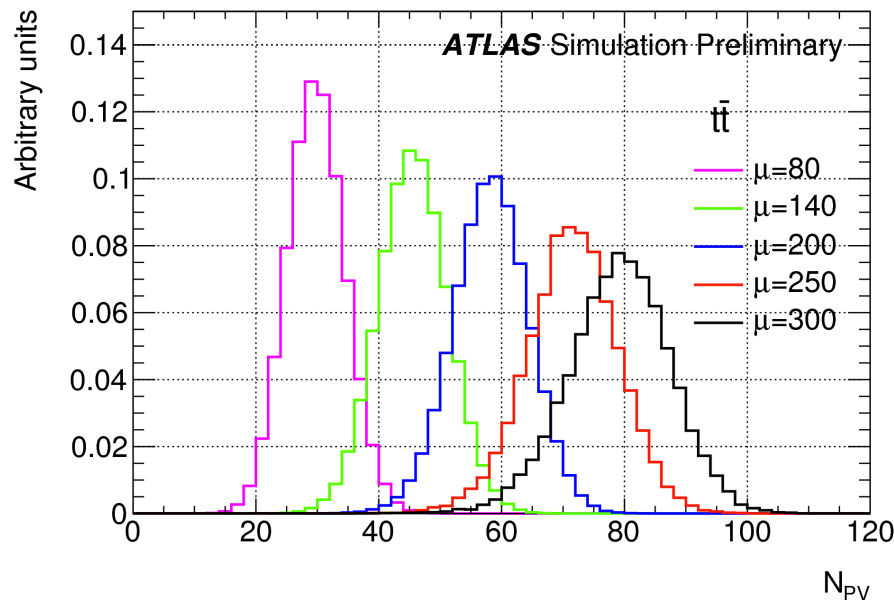
- Tracking performance studies
  - Different ITK layouts, pile-up=140
  - Efficiency, fake-rate and resolution
- ITK provides excellent tracking performance
  - Good impact parameter and  $p_T$  resolution
  - Resolution degrades in forward region



- Studies ongoing into other designs, pile-up, radiation damage
- Ultimate conclusions based on impact in physics analyses

# Primary Vertexing

- Study primary vertex performance in  $t\bar{t}$  samples
  - Lol ITK layout
  - Test five different pileup scenarios
  - Run 1 algorithms
- Performance robust even at very high pileup
  - Small drop in reconstruction efficiency at high pile-up



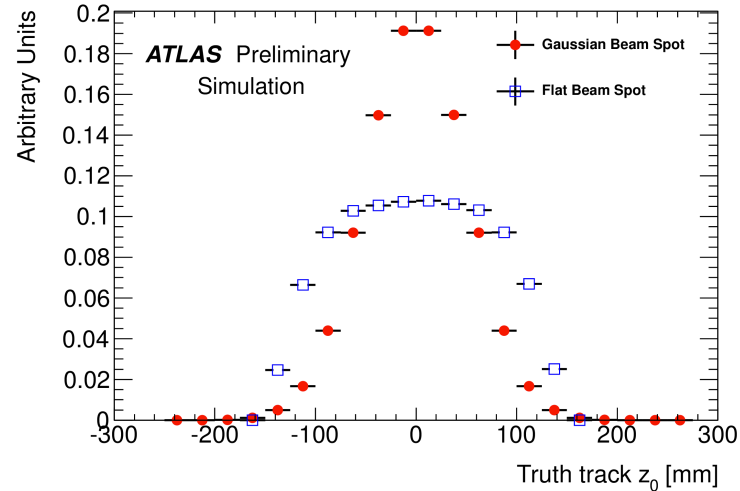
- Also studying newer algorithms and merging rate



# Beam Spot Conditions

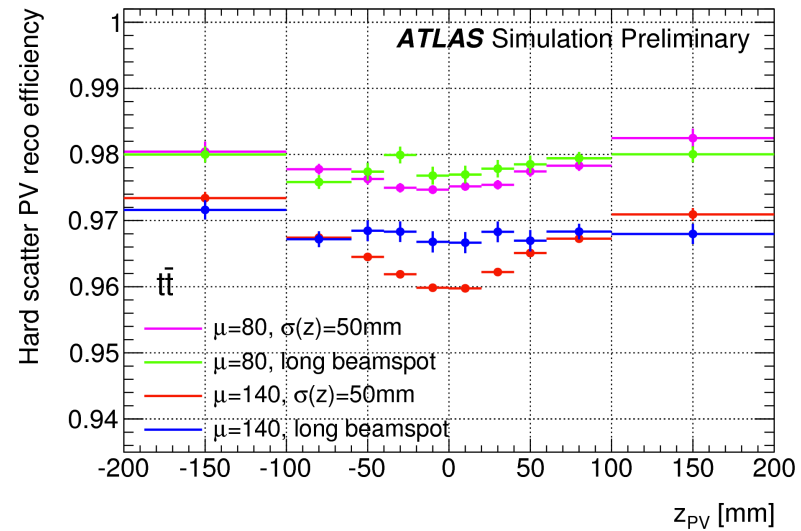
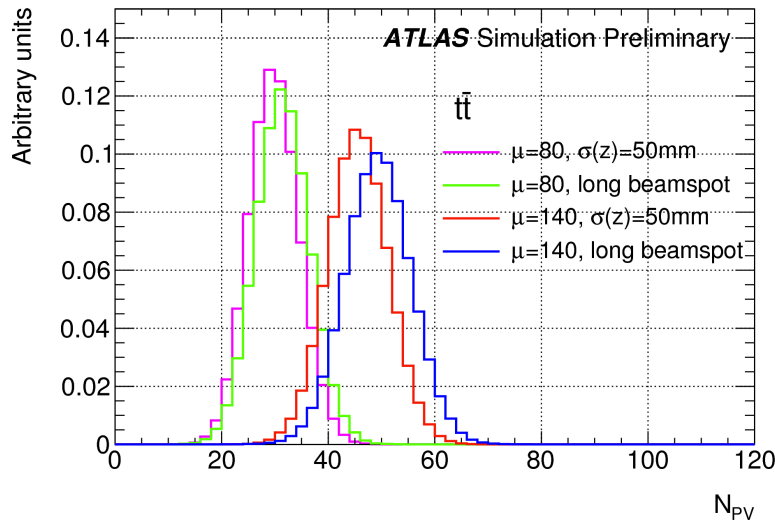
- Study impact of different detector longitudinal (z) beam spot profiles

- Gaussian with  $\sigma_z=5\text{cm}$
- Long beam spot  $\sim$ flat to  $\pm 10\text{cm}$



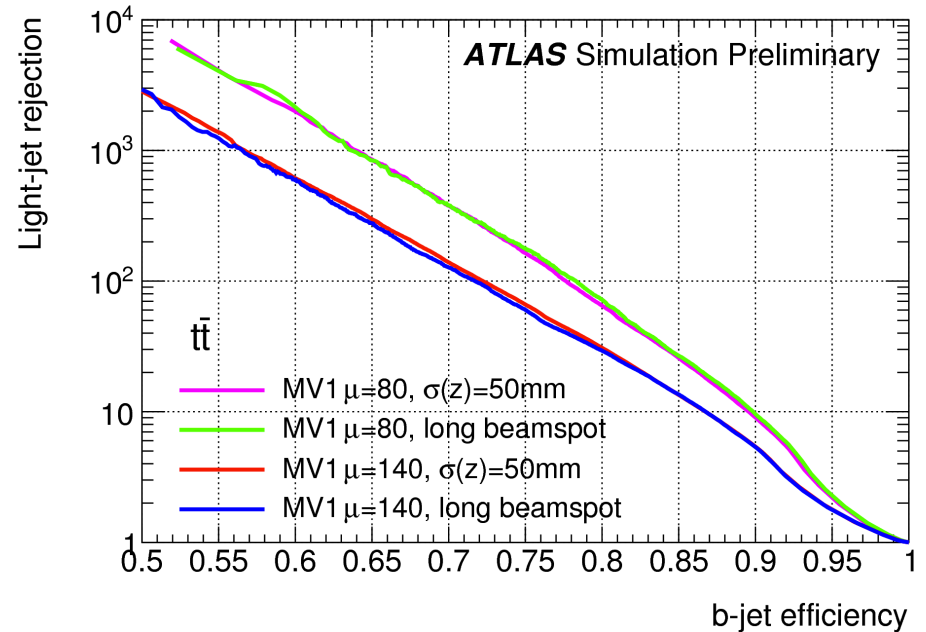
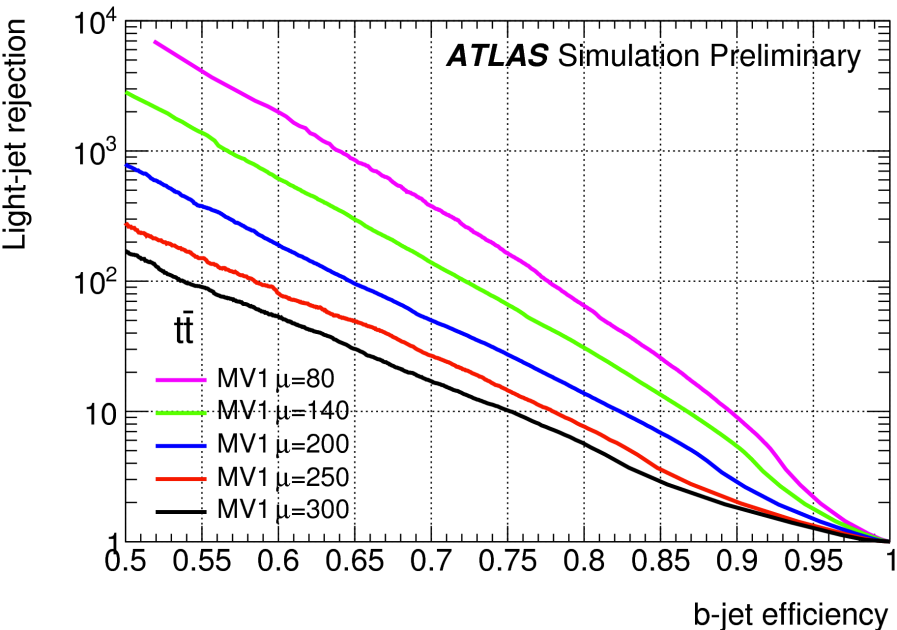
- Slightly improved performance with long beam spot

- Possibly extend study to higher pile-up and other signals



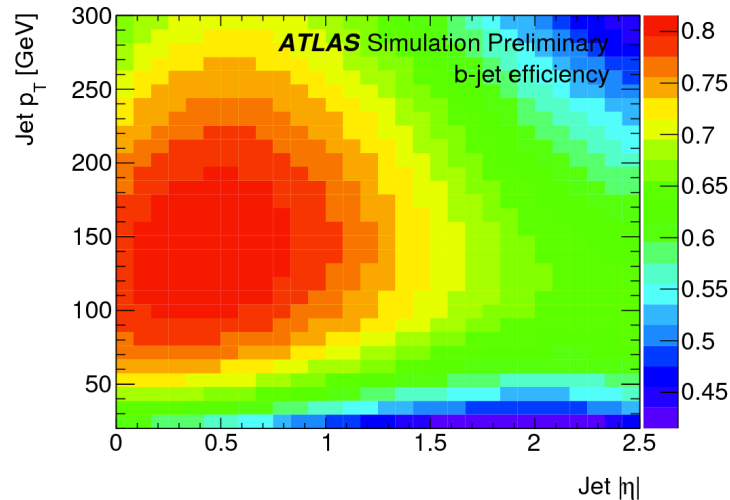
# b-Tagging

- Extend PV studies to included b-tagging
  - Requires correct hard scatter vertex found
  - Run 1 algorithms
- Performance comparisons
  - Similar performance with 140 pile-up interactions to Run 1
  - Degrades as pile-up increases
  - Insensitive to beam spot shape



# b-Tagging

- Performance used in analysis via efficiency maps
  - Parameterised  $p_T/\eta$ /flavour



**b-jet efficiency  
70% operating point**

- Work ongoing to update estimates
  - **b-Tagging in the forward region and higher  $p_T$**
  - **HL-LHC tuned/trained algorithms**
  - **Better understanding of degradation**
  - **c-jet tagging**

# Conclusions

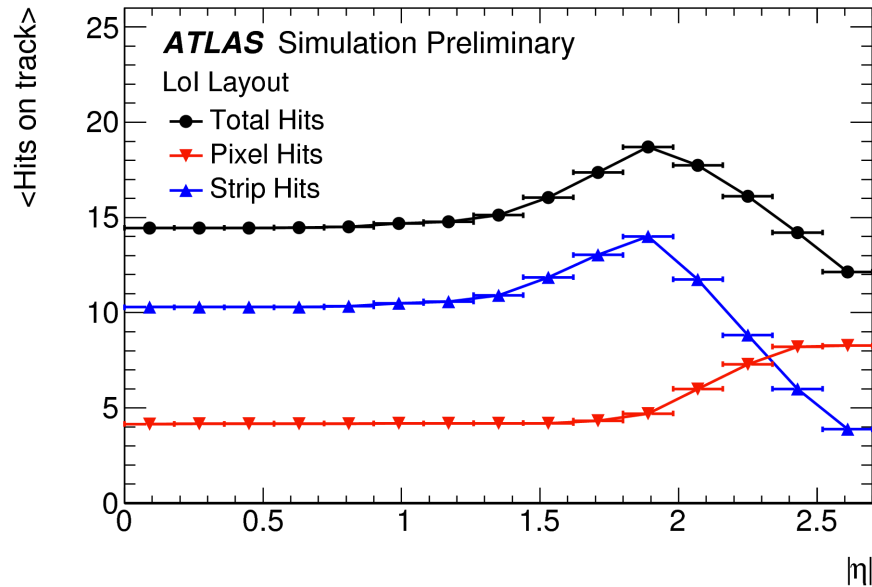
- Estimation of object reconstruction performance vital for HL-LHC studies
  - Input to physics sensitivity studies
    - Optimal HL-LHC collision configuration
    - Optimise detector design
- Many challenges
  - Different collision schemes: pile-up, beam spot shape
    - Pile-up of 200 maybe necessary to achieve  $3000 \text{ fb}^{-1}$
  - Multiple detector layouts and radiation damage scenarios
  - Algorithmic optimisation
  - **Then propagate through physics analyses**
- Promising performance at pile-up of 140
  - First measurements of performance in forward region
  - Full set of updated parameterisations later this year
  - Including updated physics sensitivity studies



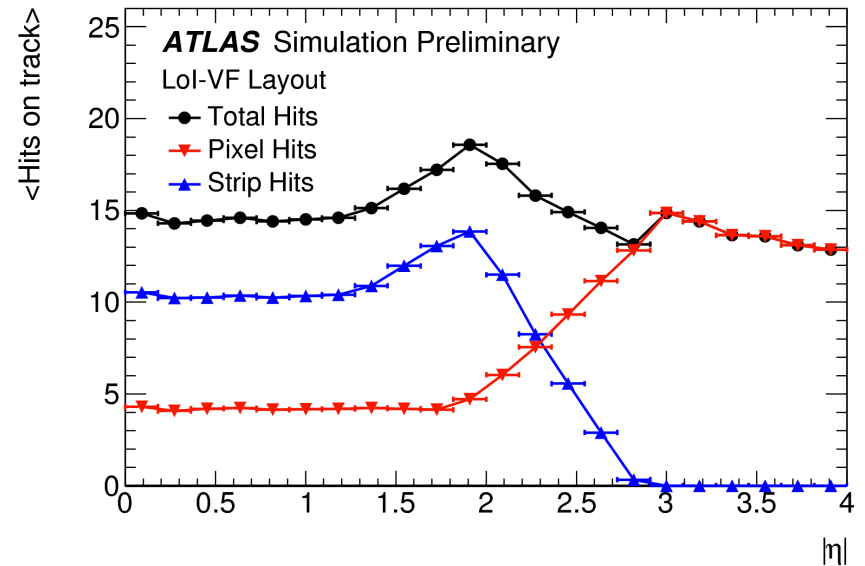
# Backup

# Hits on Tracks

- Number of inner detector hits on tracks



Lol-Layout



Lol-VF Layout

# Improved pT Resolution

- Finer granularity in forward region improves resolution

