Investigating Shower Generator Dependence of Muon Isolation Efficiency for the ATLAS Collaboration

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Muon Isolation

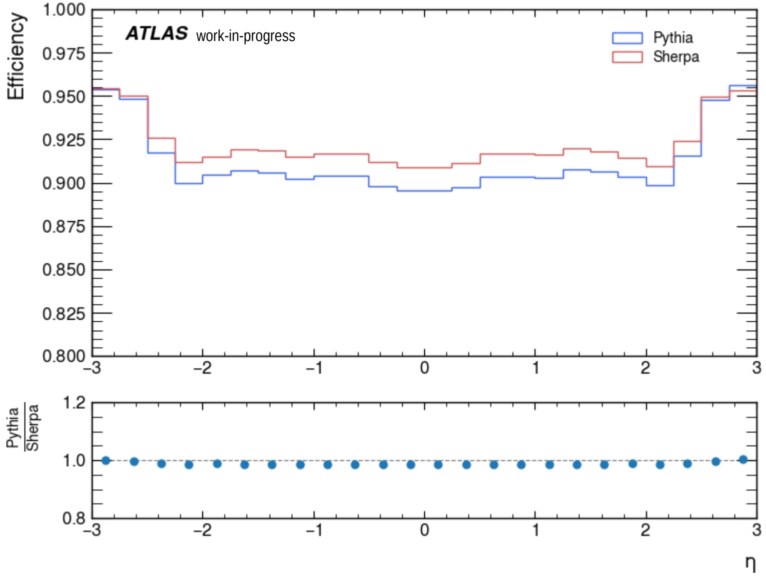
- Determine close range activity around muons to check for their isolation
- Charged contributions are evaluated by summing p_T of particles within a cone close to muons
- Only tracks with $p_T > 500$ MeV or 1 GeV are used for this calculation
- Neutral particles are accounted for by using particle flow and calorimeter energy deposits
- Use these variables together with muon p_T to create an isolation score

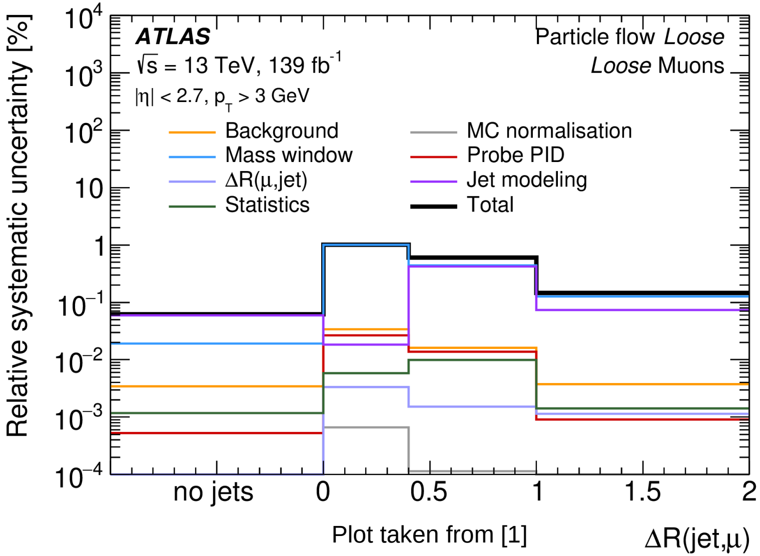
Muon Isolation Working Points & Efficiency

- Different definitions with varying isolation requirements
- General definition: track_iso + 0.4 * calo_iso < threshold * p_T
- Used in the following is: PFlow_Tight_VarRad
- Threshold value: 0.045
- Relevant variables are: $p_T^{varcone30}$ and $E_T^{neflow20}$
- Efficiency of WP defined as $\frac{\text{number of muons passing isolation WP}}{\text{total number of selected muons}}$

The Problem

- Isolation Efficiency is generator dependent
- This creates an uncertainty for analyses





Plot taken from [1]

→ Largest contribution to uncertainty for efficiency measurements

[1] The ATLAS Collaboration, Muon reconstruction and identification efficiency in ATLAS using the full Run 2 pp collision data set at $\sqrt{s}$ = 13 TeV

Methodology

- For these studies Z decays into a pair of muons are used
- Two datasets created with different shower generators: Powheg + Pythia 8 and Sherpa 2.2.11
- Compare shapes of distributions for various variables to look for inconsistencies
- Try to find the precise cause for the observed differences

→ Goal is to check if this is possible to correct for analyses

→ Reduce overall uncertainty caused by this issue

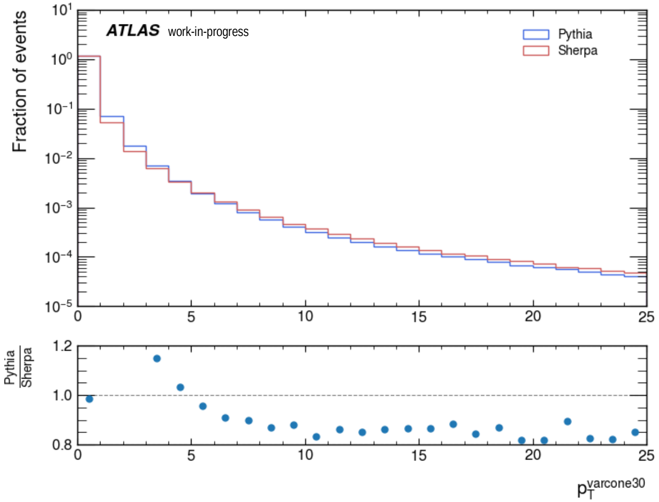
Event Selection

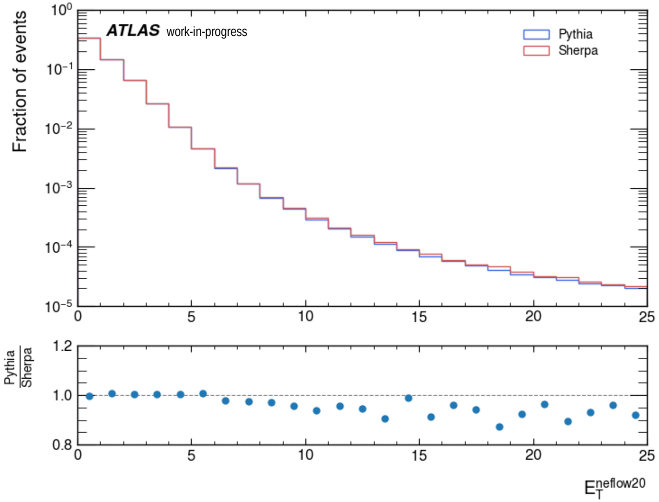
- Goal is a very clean muon selection to get rid of other analysis effects
- Use MC truth to make sure muons originated from Z boson
- Dimuon mass cut: 80 GeV < mll < 100 GeV
- Exactly 2 muons in the event
- Normalize distributions to their respective dataset
- Scale distributions from Sherpa to match those from Pythia to remove normalization differences between the generators

→ Distributions now match for most variables

→ Can start to look for inconsistencies in distributions

Isolation Variables

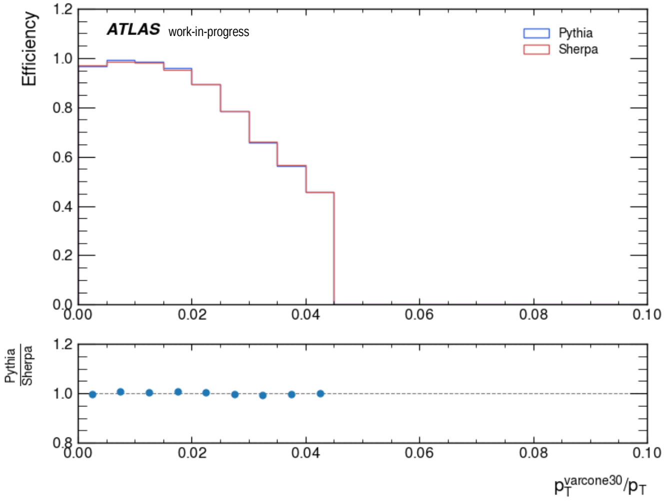


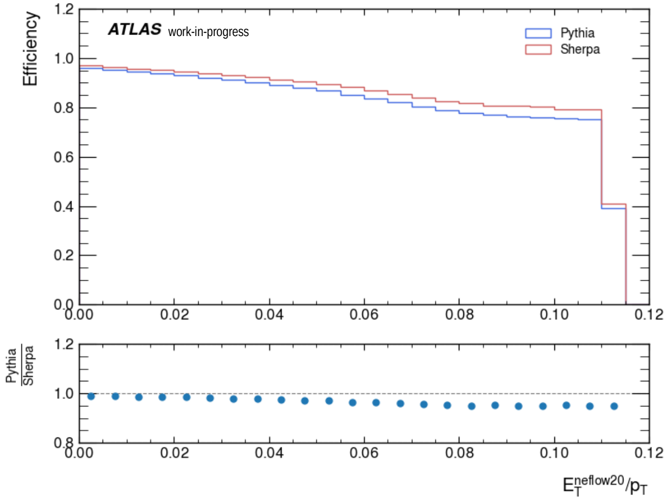


- Generator differences are visible in the isolation variables
- Inconsistencies seem to be larger for the charged tracks

Efficiency of Isolation Variables

- Allows to investigate effect of differences in isolation variables on isolation results



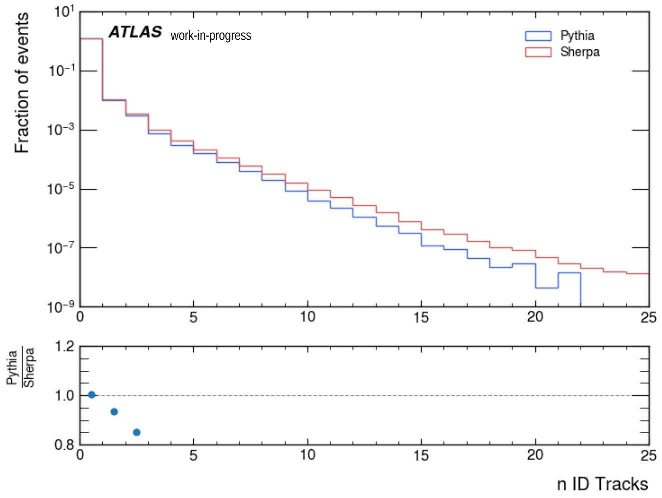


→ Efficiency unaffected by neutral particle differences

→ Efficiency significantly affected by charged track differences

Track Analysis

- Check activity around muons in inner detector
- Count number of tracks within a cone with $\Delta R < 0.3$
- Sherpa dataset shows more tracks on average
  - ▶ Extra shower particles affect isolation efficiency
  - ▶ Investigate nature of these particles



Conclusion & Outlook

- Mainly two areas interesting to check for inner detector tracks
- Currently under investigation

- Investigate MC truth of extra tracks around muons

  → Check what kind of processes are more common in Sherpa

- Implement isolation algorithm on truth level

  → Check if differences are qualitatively different for true tracks

Summary

- Investigated generator dependence of muon isolation efficiency
- Found clues hinting towards charged track isolation being the main cause of this issue
- Preliminary checks on track activity differences between generators
- Further investigate properties of extra Sherpa tracks
- Truth level isolation is also of interest

Backup