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Implementation of the Boosted DiTau Trigger Monitoring Algorithm

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Abstract

This report shows the development and integration of the class **TrigTauMonitorBoostedDiTauAlgorithm** into the ATLAS trigger monitoring system. Which is based on the existing DiTau monitoring setup but is adapted for boosted decays. The monitoring includes many kinematic and topological variables, helping to check that the triggers works as expected for Run 3 data.

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Contents

1 Introduction

The ATLAS experiment at the Large Hadron Collider (LHC) records proton–proton collisions at a frequency of up to $40\,\mathrm{MHz}$ [1]. Due to bandwidth and storage limitations, only a small fraction of these collisions can be stored for offline analysis. This selection is performed in real time by the Trigger system [2], which applies successive levels of event filtering:

- **Level-1 (L1) Trigger:** Implemented in custom electronics, which is based on energy deposits from electrons, photons, taus and jets in the calorimeter and on the pattern of ionization left by penetrating muon, reducing the rate to $100\,\mathrm{kHz}$.
- **High-Level Trigger (HLT):** Software algorithms reconstruct and select events with near offline quality, further reducing the rate to $3(10)\,\mathrm{kHz}$.

To ensure that the trigger operates as expected and meets the physics requirements, **trigger monitoring** is employed. This consists of algorithms that run the event processing at the same time to extract diagnostic variables, fill histograms, and provide immediate feedback to the shifters.

The goal of this work is to implement a new monitoring algorithm for the boosted Ditau trigger. This trigger was designed to capture events with two tau leptons produced with very high momentum, resulting in collimated decay products. This decay is relevant for searches involving heavy resonances decaying to tau pairs, such as Higgs boson pairs, in certain BSM scenarios.

2 Boosted DiTau Signatures

Tau leptons are the heaviest leptons, with a lifetime of $\sim 2.9 \times 10^{-13}$ s. They decay leptonically with a branching ratio BR$(\tau \to e/\mu + \bar{\nu}_{e/\mu} + \nu_\tau) \sim 0.35$, and hadronically with BR$(\tau \to \text{mesons} + \nu_\tau) \sim 0.65$ [3]. In particular, we focus here on the latter decays, which produce narrow jets characterized by:

- low track multiplicity {1,3}.
- a high fraction of energy deposited in the electromagnetic calorimeter.
- isolation from other high-p_T tracks and calorimeter deposits.

In the boosted regime, the decay products of the two tau leptons are close in angular separation $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$ ($\Delta R \sim 2m_H/p_T$[1]), often leading to:

- collimated signatures with overlapping decay products.

[1]Assuming the Higgs is decomposed in two particles, carrying on the larger fraction of the original Higgs p_T

- merged track signatures.
- reduced performance of isolation variables.

These effects require specialized trigger algorithms with optimized reconstruction and identification, as well as tailored monitoring to ensure efficiency and stability.

3 Algorithm Implementation

The Trigger Monitoring for Boosted DiTau is implemented within the TrigTauMonitoring package and follows the standard structure of ATLAS monitoring algorithms, but is adapted for boosted di-tau triggers.

The Diagram 1 illustrates the workflow, We start from AOD inputs, the algorithm retrieves the relevant HLT chain names and obtain the features of the Trigger Decision Tool (TDT). Using this information, it retrieves the `xAOD::DiTauJet` objects. Finally, for each objet, the algorithm reads the first Ditau candidate, extracts all relevant variables, and fills histograms in the monitoring group.

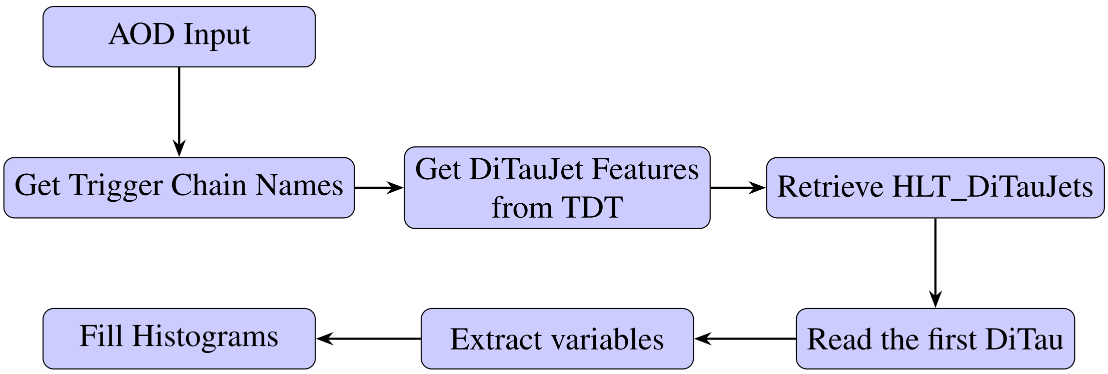

Figure 1: Workflow overview of the boosted di-tau monitoring algorithm.

Table 1 lists the monitored variables and their physical meaning. Currently the algorithm only plots these variables, but we are in the process of implementing the trigger efficiency measurement by first selecting the offline DiTau candidates.

Table 1: Monitored variables and their physical meaning.

Variable	Description
omni_score	Multivariate score indicating the quality of Ditau identification.
R_tracks_lead	Average distance of all tracks around the leading tau, weighted by their transverse momentum.
R_tracks_subl	Average distance of all tracks around the subleading tau, weighted by their transverse momentum.
f_core_lead	Fraction of the leading taus energy concentrated in its core region.
f_core_subl	Fraction of the subleading taus energy concentrated in its core region.
n_track	Total number of tracks linked to the Ditau candidate.
n_tracks_lead	Number of tracks associated with the leading tau.
n_tracks_subl	Number of tracks associated with the subleading tau.
$p_T(\tau\tau)$	Transverse momentum of the Ditau system.
$\eta_{\tau\tau}$	Pseudorapidity of the Ditau system.
$\phi_{\tau\tau}$	Azimuthal angle of the Ditau system.
$m_{\tau\tau}$	Invariant mass of the Ditau system.

4 Results

The integrated algorithm has been successfully deployed and validated. Two merge requests were submitted and accepted.

1. The first implementation of boosted DiTau monitoring algorithm !81928.
2. Another version is based on retrieving the objects using the TDT features and adding new variables !81928.

Example histograms are shown in Figures 2, 3, and 4[2].

[2]These histograms were generated using the dataset `data25 13p6TeV.00502896.physics_Main.merge.AOD.f1612_m2272` and the chain `HLT_j250_a10sd_cssk_ditauOmni1Trk5_pf_jes_ftf_preselj200_L1gLJ140p0ETA2`.

5 Conclusions

The class **TrigTauMonitorBoostedDiTauAlgorithm** was successfully implemented in the ATLAS monitoring framework and does the following:

- Covers many variables for boosted DiTau triggers, like kinematics, and variables used to train the trigger.
- Extract the variables using the features of the TDT.
- We successfully implemented two merged requests.

This helps check that boosted Ditau triggers work well during Run 3 and can be used as a reference for other analyses of high-boost decays in ATLAS.

References

[1] ATLAS Collaboration. The ATLAS Experiment at the CERN Large Hadron Collider: Run 3 configuration and performance. *Journal of Instrumentation*, 19(05):P05063, May 2024.

[2] ATLAS Collaboration. The ATLAS trigger system for LHC Run 3 and trigger performance in 2022. *Journal of Instrumentation*, 19(06):P06029, June 2024.

[3] Particle Data Group Collaboration. Review of particle physics. *Phys. Rev. D*, 110:030001, August 2024.

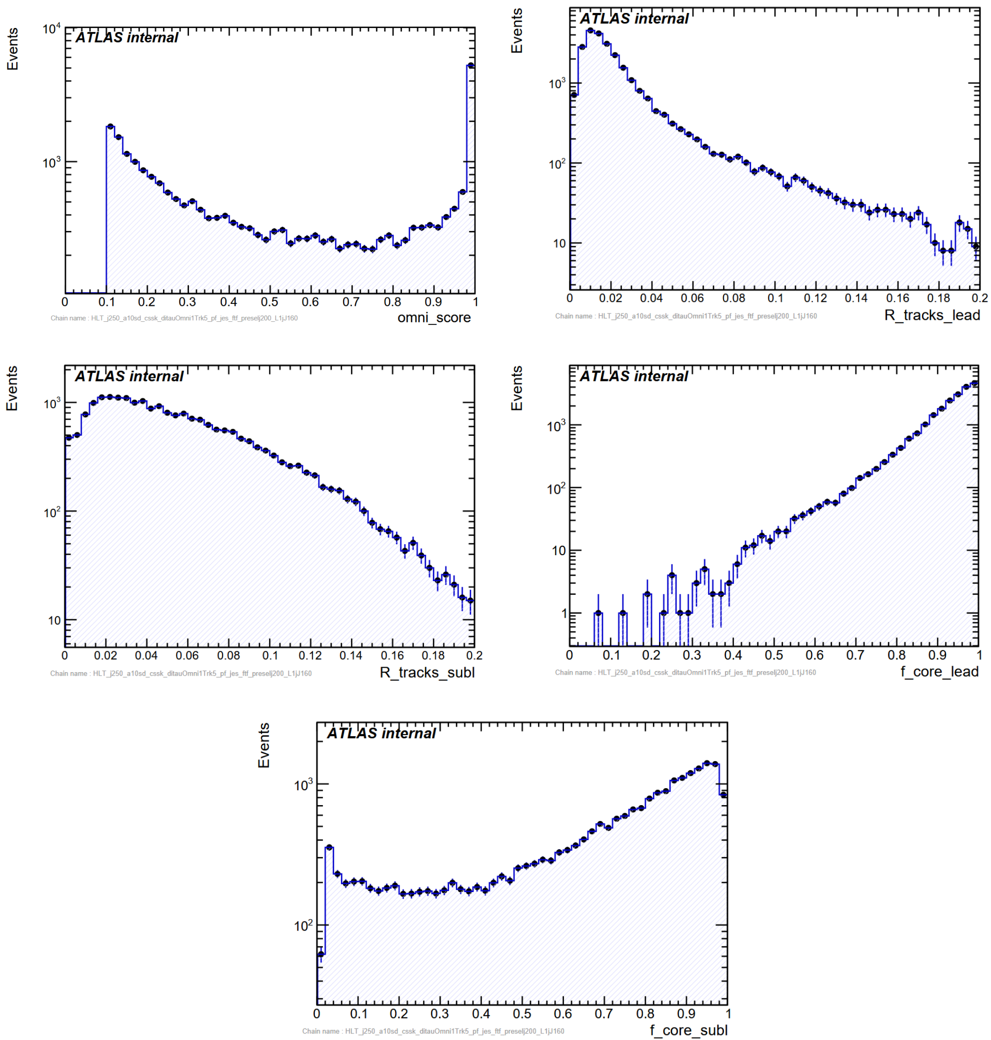

Figure 2: Distributions of general variables. The top left shows the Omni score, the top right the leading-track R_{tracks}, the middle left the subleading-track R_{tracks}, the middle right the leading-track f_{core}, and the bottom left the subleading-track f_{core}.

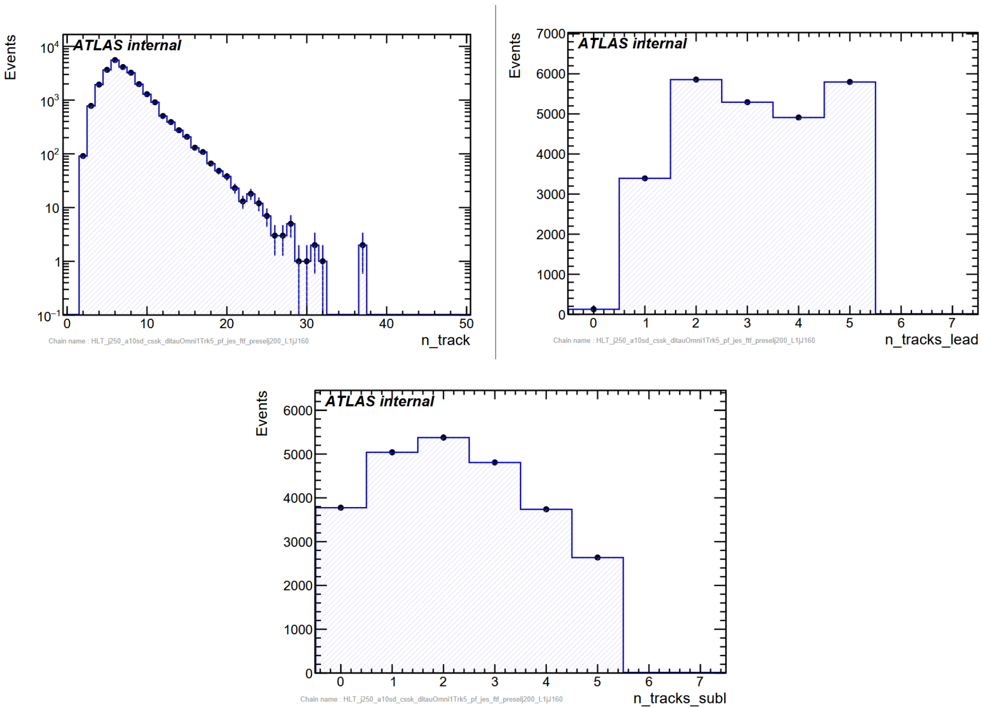

Figure 3: Distributions of variables related to the number of tracks. The top left shows the total number of tracks, the top right the number of tracks associated with the leading τ, and the bottom left the number of tracks associated with the subleading τ.

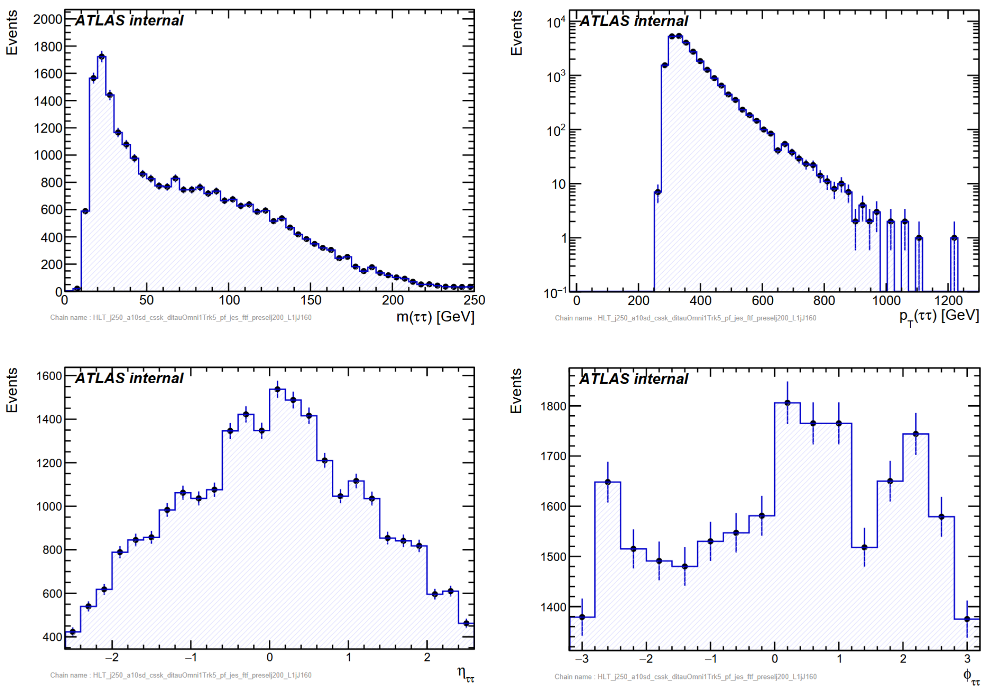

Figure 4: Distributions of kinematic variables. the top left shows the di-tau mass, the top right the di-tau transverse momentum, the bottom left the pseudorapidity (η), and the bottom right the azimuthal angle (ϕ).