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GEFÖRDERT VOM Bundesministerium für Bildung und Forschung
CERN
CMS Compact Muon Solenoid
42ND INTERNATIONAL CONFERENCE ON HIGH ENERGY PHYSICS 18-24 July 2024

Machine Learning based Tau Lepton Identification for the CMS High-Level Trigger deployed for 13.6 TeV proton-proton collisions

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on behalf of the CMS Collaboration

ICHEP 2024, Prague 17-24 July

Tau Leptons (τ): The Heavyweights of Particle Physics

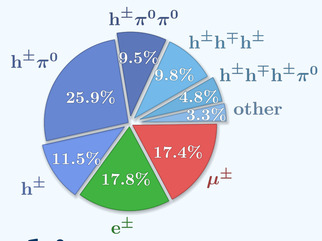
Mass: 1776.86 MeV/c²
Average lifetime: 2.9x10^{-13} s
Spin: ½ (fermion)
Discovery: 1974
Unique feature: *only lepton that can decay to hadrons*
Significant role: Yukawa couplings of Higgs, CP properties of Higgs, Leptoquarks, High mass resonances, Search for Lepton Flavor Violation, etc.

Taken from https://cds.cern.ch/record/1473657

Unveiling τ leptons in CMS

Tau decay analysis:

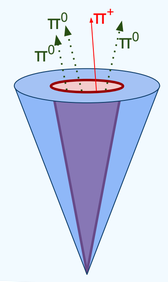
~35% fully leptonic decays
~65% hadronic decays (τ_h)

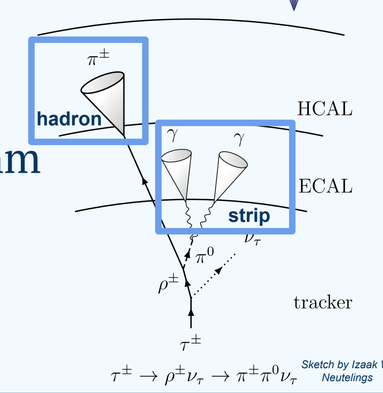


τ_h appears as a **collimated, isolated jet**

τ_h reconstructed from its decay products using **Hadron-Plus-Strips (HPS)** algorithm

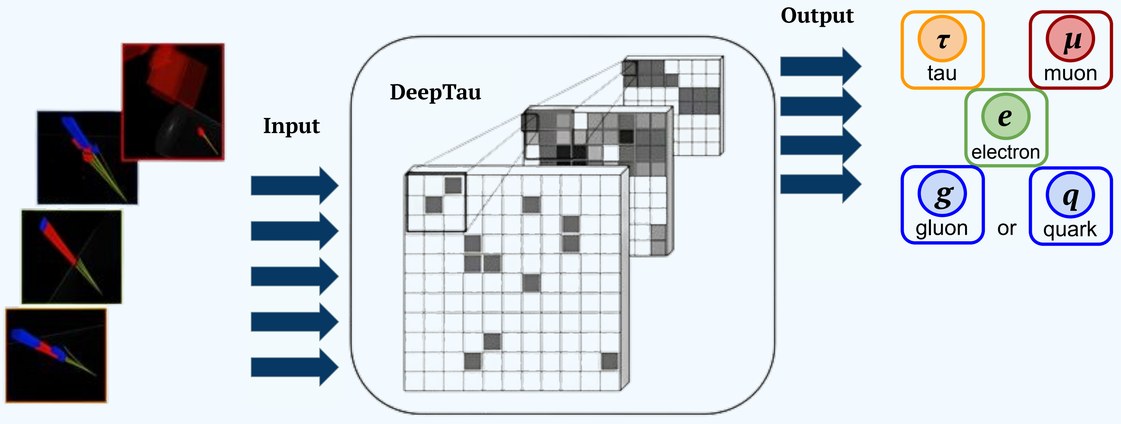
Convolutional Neural Network (CNN)-based DeepTau algorithm (v2.5) used to reduce misID as jets, e, μ





The AI Wizard of Tau Identification

DeepTau v2.5 performs better than its previous version (2.1) and is used for Run-3 analyses

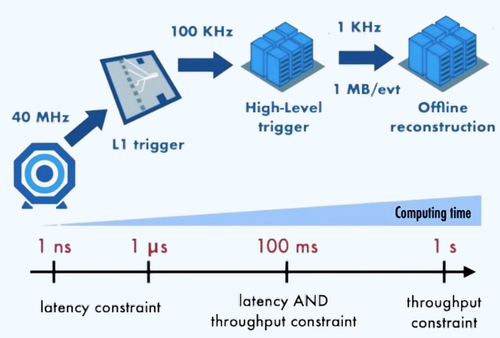


Main Enhancements: balance across phase spaces, reduced mismoddeling in MC simulations

Catching Taus: Inside the CMS Trigger System

τ_h reconstruction from trigger's PoV:

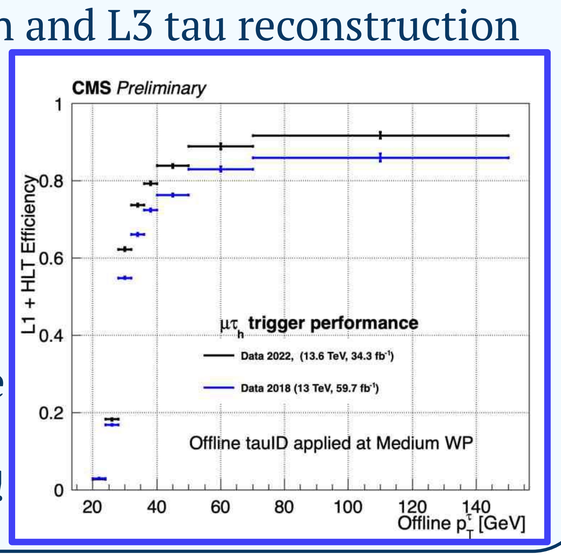
Level 1 (L1):
Calibration of Trigger Towers to mimic true offline response, clustering around a central seed, and merging clusters to form L1 taus



High-Level Trigger (HLT):
L2 builds calorimeter jets around L1 seeds, L2.5 uses pixel track-based isolation for L2 hadronic tau leptons, followed by Particle-Flow event reconstruction and L3 tau reconstruction

Improvements for τ_h RECO at HLT for Run-3 w.r.t. Run-2:

L2TauNNTag@HLT (L2 + L2.5, CNN-based algorithm for τ_h tagging),
DeepTau@HLT (L3, from Particle Flow),
New trigger paths & many more!

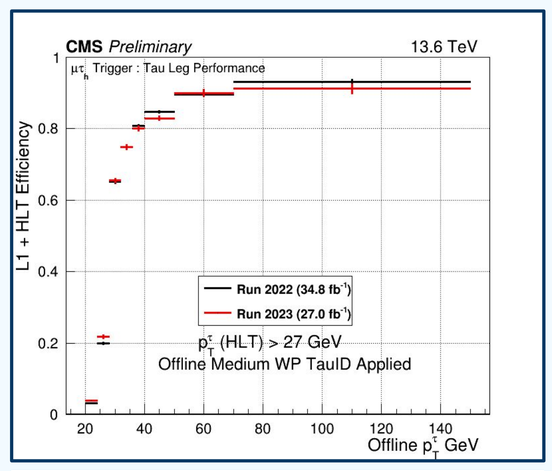


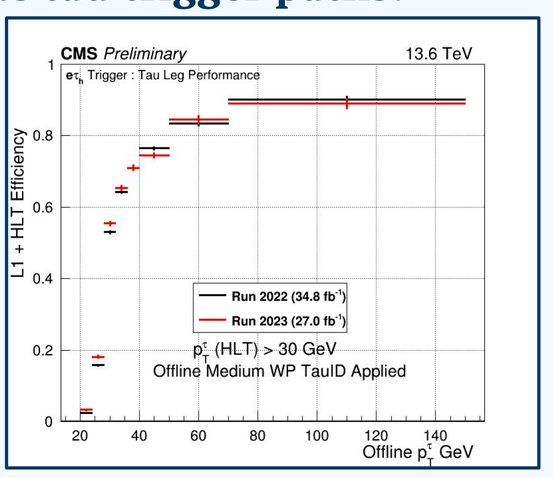
Tau Lepton Triumphs: Performance of τ reconstruction at HLT

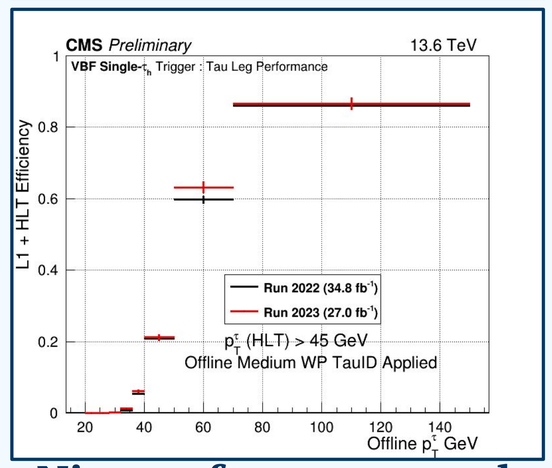
★ Studies on the reconstruction **efficiency of τ_h leptons @ HLT** performed using **2022 and 2023 (Run-3) data** collected at **$\sqrt{s}$ = 13.6 TeV** of pp collisions at LHC
★ Hadronic tau performance is measured using the Tag and Probe technique with IsoMu24 triggers (p_T > 24 GeV), focusing on $Z \to \tau\tau \to \mu\tau_h$ decays
★ Tau trigger object efficiency is calculated as follows:

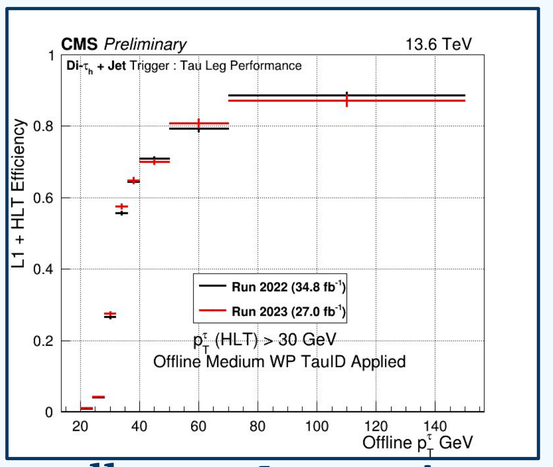
$$\frac{\text{IsoMu24 Trigger} + \text{Monitoring Trigger} + \text{Offline Selection} + \text{match } \tau^{HLT}}{\text{IsoMu24 Trigger} + \text{Offline Selection}}$$

Performance results for various tau trigger paths:









Nice performance can be seen all over p^{τ}_T range!

References

- CMS collaboration, Identification of hadronic tau lepton decays using a deep neural network, 2022 JINST 17P07023
- CMS collaboration, Performance of tau lepton reconstruction at High Level Trigger using 2022 data from the CMS experiment at CERN, 2022 CERN Detector Performance Summaries, CMS-DP-2023-024
- CMS collaboration, Performance of Tau Lepton Reconstruction at the High Level Trigger using 2023 Data from the CMS Experiment at CERN, 2023 CERN Detector Performance Summaries, CMS-DP-2024-042
- CMS collaboration, Performance of the DNN-based tau identification algorithm (DeepTau v2.5) with Domain Adaptation using Adversarial Machine Learning for Run 2, CMS-DP-2024-XXX