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Reconstruction and identification of hadronic tau at 13 TeV

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Introduction

"Performance of reconstruction and identification of τ leptons decaying to hadrons and vτ in pp collisions at √s=13 TeV"

- Paper published in September 2018: **JINST 13 (2018) no. 10, P10005**
- arXiv:1809.02816 (link here)
- Algorithm developed by the CMS Collaboration to reconstruct and identify hadronically decaying τ leptons produced in pp collisions

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Performance of reconstruction and identification of τ leptons decaying to hadrons and ν_τ in pp collisions at $\sqrt{s} = 13$ TeV

The CMS collaboration

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Abstract: The algorithm developed by the CMS Collaboration to reconstruct and identify τ leptons produced in proton-proton collisions at $\sqrt{s}$ = 7 and 8 TeV, via their decays to hadrons and a neutrino, has been significantly improved. The changes include a revised reconstruction of π^0 candidates, and improvements in multivariate discriminants to separate τ leptons from jets and electrons. The algorithm is extended to reconstruct τ leptons in highly Lorentz-boosted pair production, and in the high-level trigger. The performance of the algorithm is studied using proton-proton collisions recorded during 2016 at $\sqrt{s}$ = 13 TeV, corresponding to an integrated luminosity of 35.9 fb^{-1}. The performance is evaluated in terms of the efficiency for a genuine τ lepton to pass the identification criteria and of the probabilities for jets, electrons, and muons to be misidentified as τ leptons. The results are found to be very close to those expected from Monte Carlo simulation.

Keywords: Large detector-systems performance; Particle identification methods; Performance of High Energy Physics Detectors

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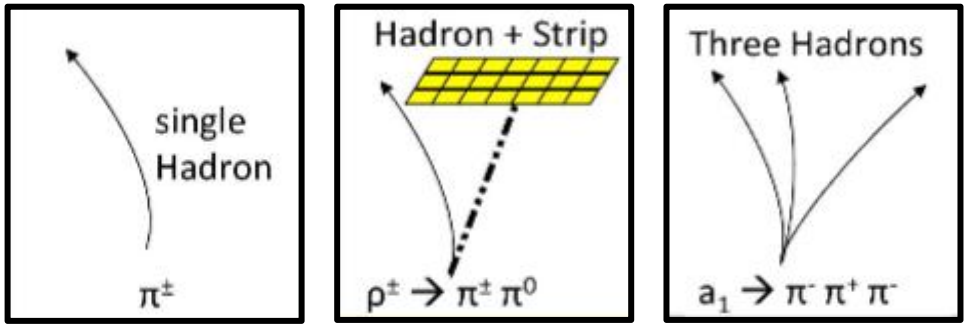
Introduction

- The τ lepton is the only lepton to decay into hadrons (64.8%)
- In CMS hadronic τ are reconstructed and identified using the hadrons-plus-strips (HPS) algorithm

Decay mode	Resonance	$\mathcal{B}$ (%)
Leptonic decays		35.2
$\tau^- \to e^- \bar{\nu}_e \nu_\tau$		17.8
$\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$		17.4
Hadronic decays		64.8
$\tau^- \to h^- \nu_\tau$		11.5
$\tau^- \to h^- \pi^0 \nu_\tau$	$\rho(770)$	25.9
$\tau^- \to h^- \pi^0 \pi^0 \nu_\tau$	$a_1(1260)$	9.5
$\tau^- \to h^- h^+ h^- \nu_\tau$	$a_1(1260)$	9.8
$\tau^- \to h^- h^+ h^- \pi^0 \nu_\tau$		4.8
Others		3.3



New features introduced in Run II:

1. **Dynamic-strip reconstruction** → change the size of the strip in a dynamic way to reconstruct the decay products from the π^0 more effectively
2. Improvements in the **MVA discriminants** to reduce fakes from jets/electrons
3. HPS extended to reconstruct **τ pairs from boosted resonances**
4. Dedicated τ_h identification defined at **high-level triggers**

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PAPER

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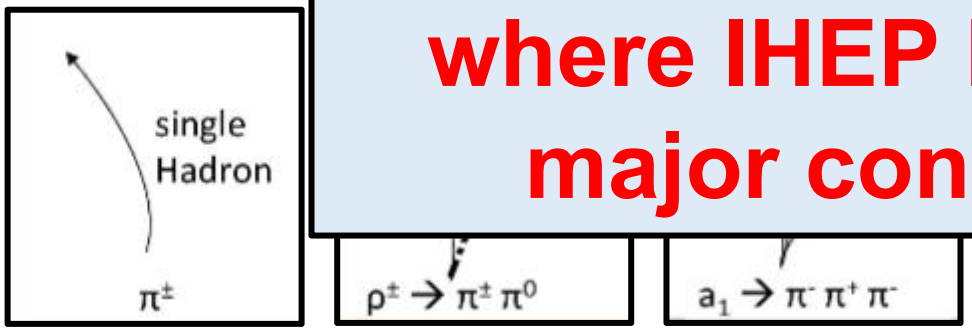
		4.8
		3.3

In the next I will focus on boosted tau reconstruction where IHEP have had a major contribution



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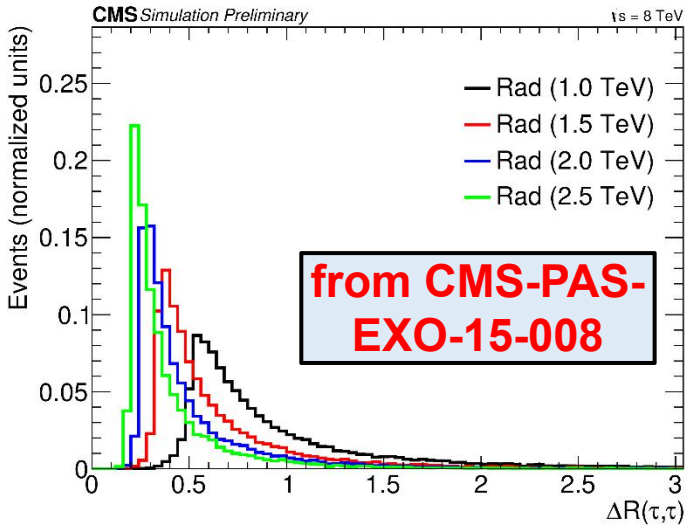
Highly-boosted τ pairs

Heavy resonances with M ≥ 1 TeV ends with tau pairs produced **close to each other** → if ΔR(τ,τ) < 0.4, a new approach is needed

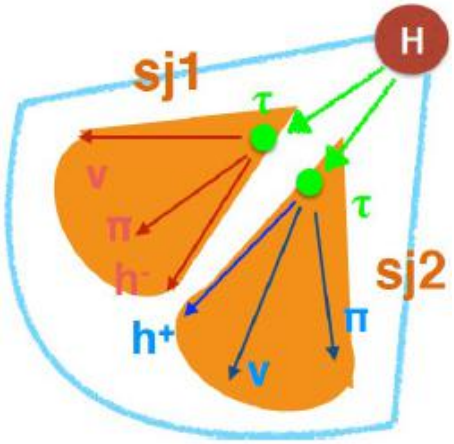


- Massive boson with large pt, for example a radion decaying to HH and with at least one H decaying to a pair of τ leptons → **the jets from the two τ are emitted very close to each other**
- The performance of the standard HPS algorithm in such topologies is poor, as it was designed to reconstruct only one single τ lepton
- A **dedicated version of the HPS algorithm** is developed to reconstruct the two τ with large momenta emitted very close to each other
- This algorithm takes advantage of **jet substructure techniques**

Highly-boosted τ pairs

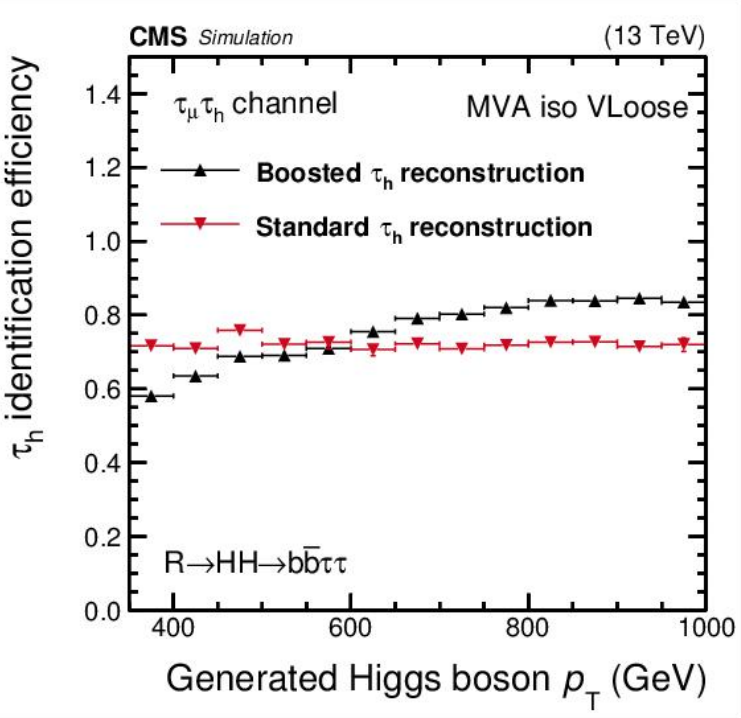
Algorithm workflow:

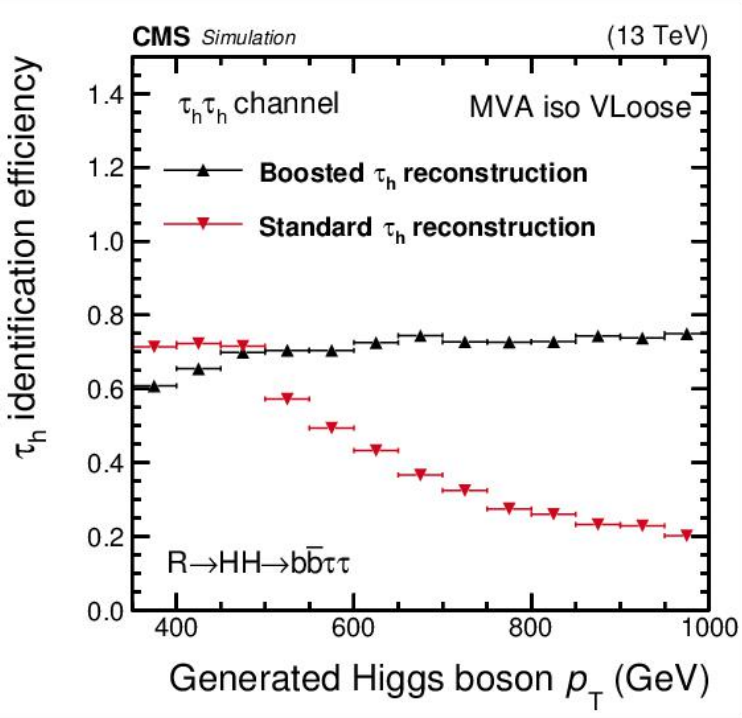
- Starting from large radius jet with pt > 100 GeV
- Look for **two subjets** inside it → **they are expected to be the two τ from the boosted H**
- the pt of each subjet must be > 10GeV
- mass of the heaviest subjet less than 2/3 of the fat jet mass
- if no subjets pair is found, the procedure is repeated treating the subjet with highest mass as initial jet and splitting it into two new subjets



Subjets are fed to the hadrons-plus-strips algorithm as tau candidates

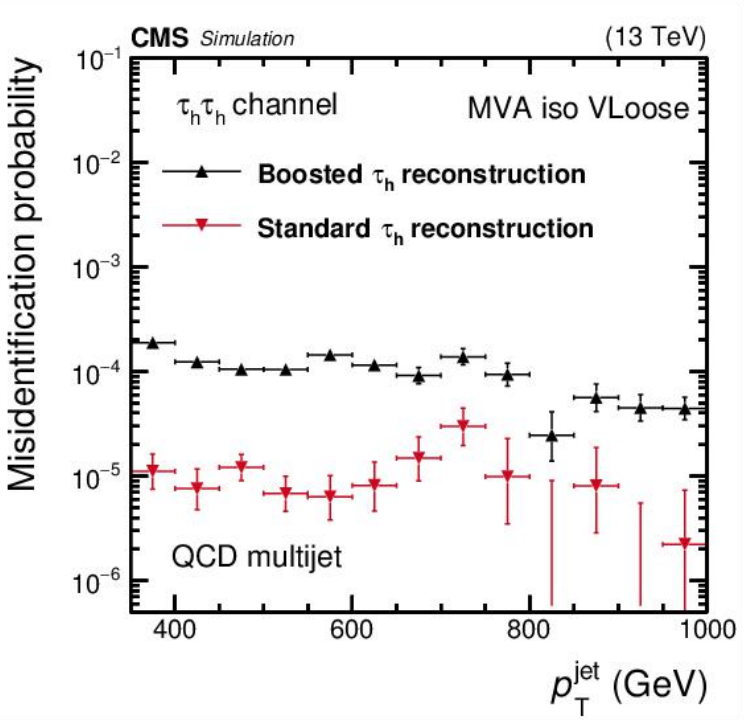
Tau identification efficiency





- Comparison of the **efficiencies** between **standard reconstruction versus boosted reconstruction** in simulated events of radion → HH → bbττ in the $\tau_\mu\tau_h$ (left) and $\tau_h\tau_h$ (right) final state
- The algorithm used for highly boosted events provides a **considerably higher efficiency** than the standard HPS algorithm for τ lepton pairs with pt greater than ≈ 0.5 TeV

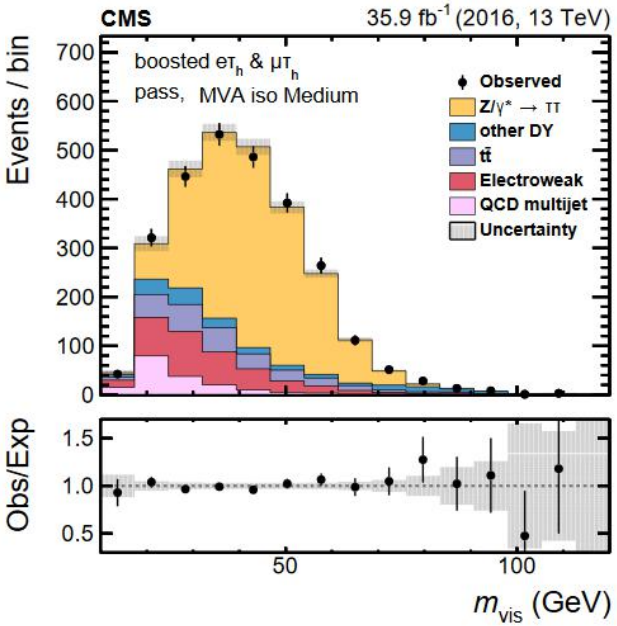
Misidentification probability

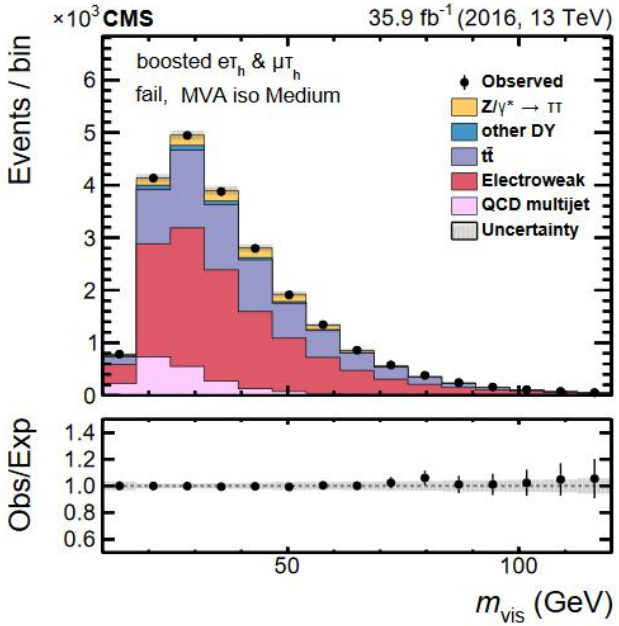


- Expected probability for large-radius jets to be misidentified as hadronic τ pairs is shown for simulated QCD multijet event

Performances in data

- Performances measured in **boosted Z → ττ events**, with one τ decaying hadronically and the other to **muon/electron**
- The **ΔR(lep,τ)** is considered between 0.4 and 0.8
- Maximum-likelihood fit of **visible mass** performed in three regions
- Scale factors compatible with the ones obtained for standard τ





Working point	Scale factor
Very loose	0.97±0.09
Loose	0.99±0.09
Medium	0.98±0.09
Tight	0.96±0.08
Very tight	0.95±0.09
Very-very tight	0.90±0.08

Conclusion

- The paper describes the **performance of reconstruction and identification of τ_h at 13 TeV**
- Several **improvements and new features** with respect to the Run-1 algorithm (link here) have been obtained
- Between them, reconstruction of **τ_h pairs coming from boosted resonances** (Z/H bosons)
- The algorithm has been shown to be **a powerful tool to reconstruct τ_h leptons in CMS**