Performance of the ATLAS tau-lepton trigger at the LHC in Run 2

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ATLAS Tau Trigger System

Why is the tau-lepton important?

Tau-leptons play an important role in the Standard Model measurements, especially Yukawa coupling and searches for physics Beyond the Standard Model in the ATLAS experiment

What is a tau-lepton?

The heaviest 3rd generation lepton

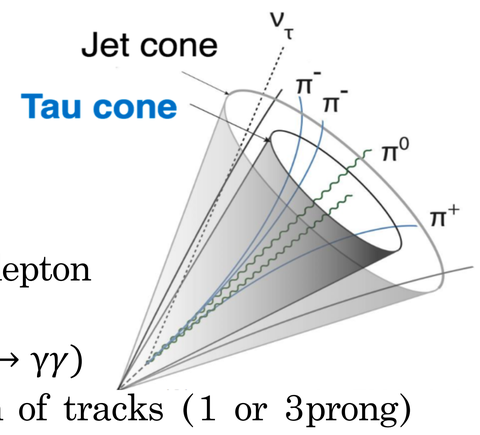
$$m_\tau = 1.777GeV, c\tau = 87\mu m,$$

Decays : $\tau \to l\nu_l\nu_\tau(35\%), \tau \to hadron(s) + \nu_\tau(65\%)$

Leptonic decays are reconstructed as prompt light lepton

Vocabulary @ LHC :

tau = hadronic tau = the collection of $\pi^{\pm}$ *and* $\pi^0(\to \gamma\gamma)$



Signature : calorimeter deposit with the association of tracks (1 or 3prong)

Sophisticated Offline Tau Recontruction

Current Tau reconstruction uses many Boosted Decision Tree algorithms.

- Track Classification : Charged, Conversion, Isolation and Fake tracks
- Identification : 1p vs QCD jet, 3p vs QCD jet
- Decay Classification 5 modes : 1pXn(X=0,1,>=2), 3pXn(X=0,>=1)
- Electron Veto : 1p tau vs Electron
- Energy Calibration : Calo-based energy scale or Regression for True p_T

ATLAS Tau Trigger System

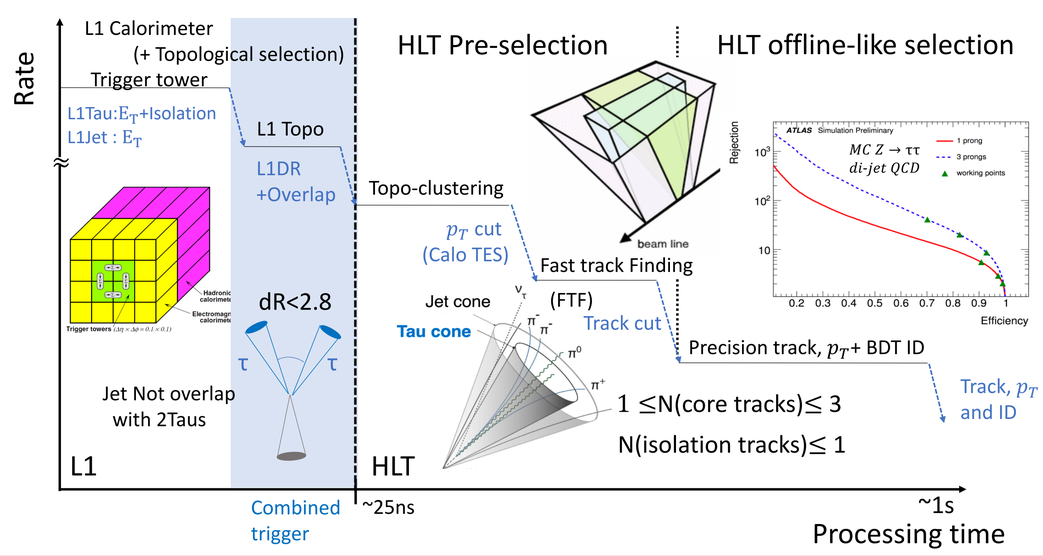
- Level-1 : Hardware system using calorimeter tower Core(EM2×1, HAD2×2) and Isolation(4×4-2×2) energy. The maximum allowed energy in the isolation ring.

e.g.) Iso≤3(≤7)GeV @ core=12(50)GeV

L1 Topological Trigger can suppress the rate by topological criteria

- High Level Trigger : Software system similar to offline

p_T cut, track selection in 2 stages and BDT identification



Tau Trigger Menu in Run 2

Primary tau triggers in Run 2

Trigger	p_T thresholds in GeV	
	L1	HLT
Single-tau	100	160
Di-tau	40, 60	60, 80
Di-tau+jet w/L1topo	12I, 20I dR<2.8, 25(jet)	25, 35
Tau+e	12I, 15I(e), 25(jet)	25, 17(e)
Tau+μ	12I, 10(μ), 25(jet)	25, 14(μ)
Di-tau+E_T^{miss}	12I, 40, 40(E_T^{miss})	25, 60, 50(E_T^{miss})

I…Isolation cut @ L1, E_T^{miss}…Missing Transverse Energy

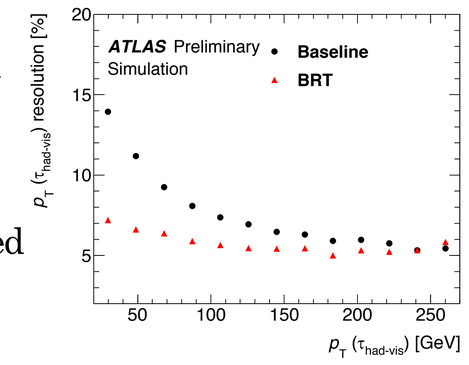
New Tau Trigger menu in 2018

- BDT ID (w/o Ntrack presel): The track multiplicity requirement is only applied to tracks from precision tracking reconstructed at a later HLT stage

- BRT calibration and RNN ID trigger : Boosted Regression Tree for energy calibration and Recurrent Neural Network algorithm for tau identification are more similar to offline tau.

Energy resolution with BRT has a big improvement at low p_T, RNN ID provides increased jet rejection compared to BDT ID.

The 2 HLTs have comparable trigger rate.

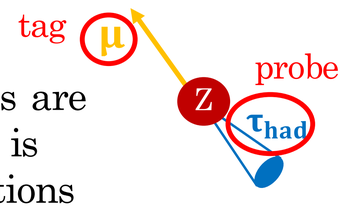


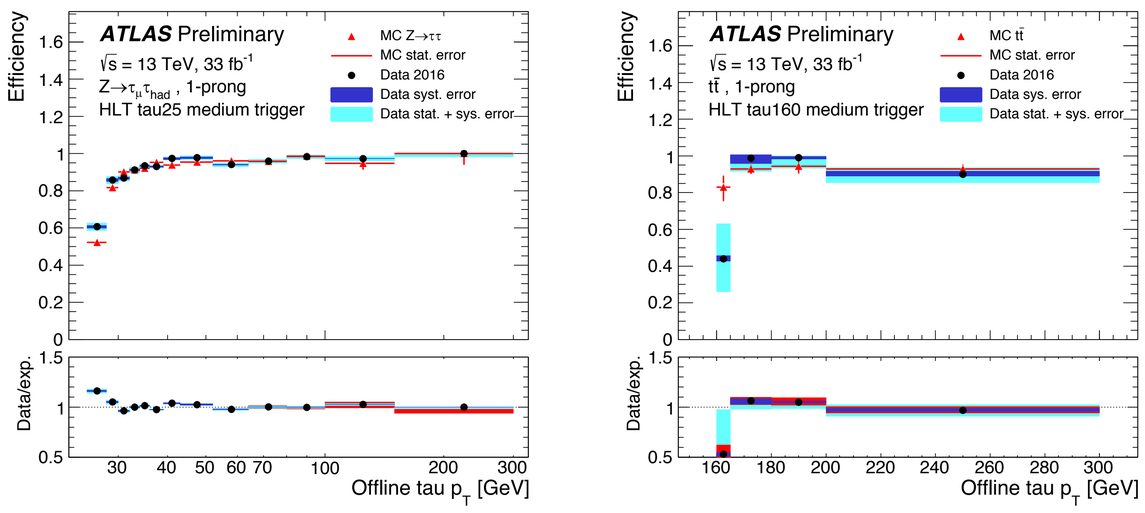
Performance of Tau Trigger in Run 2

Tag & Probe

Trigger efficiencies are measured by using $Z \to \tau\tau \to \mu\tau_h$ events. The dominant backgrounds are W+jets and QCD multi-jets events, where a jet is mis-identified as tau candidate. These contributions are estimated to use data-driven techniques.

We extend p_T range by using $t\bar{t}$ events for high p_T.



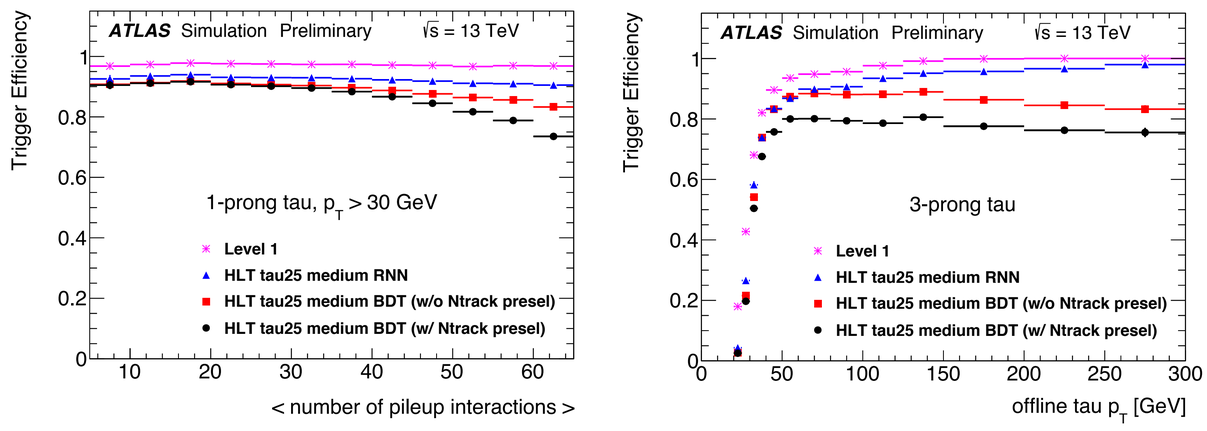


Improvement of HLT algorithm in 2018

Coping with pileup and High p_T optimization

The inefficiency of the Ntrack preselection at high pileup is due to the larger number of fake tracks reconstructed from random hits alignment in the inner detector. New triggers reduce the inefficiencies at high pileup.

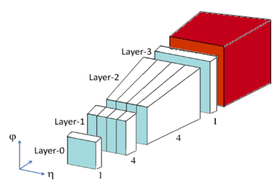
At high p_T, RNN trigger looses the requirement of Ntrack, and RNN IDs are trained for 0- and 2-prong tau too.



Prospect for Run 3

- The improvement of energy resolution at Level-1 trigger

Trigger readout system will be upgraded to super-cell from trigger tower. This system improves the resolution and efficiency for selecting objects, while enhancing discrimination against backgrounds and fakes with high instantaneous luminosity.



- Fast Tracker Hardware system(FTK)

FTK processor receives data from ATLAS detector for all events accepted by the L1 trigger at 100k events. FTK makes it possible to use track information in HLT at the initial stage. Then, we can add FTK track and vertex information to current BRT and BDT inputs (similar to offline algorithm).

Reference

The ATLAS Collaboration, The ATLAS Tau Trigger in Run 2, ATLAS-CONF-2017-061

The ATLAS Collaboration, Measurement of the tau lepton reconstruction and identification performance in the ATLAS experiment using pp collisions at $\sqrt{s}$=13 TeV, ATLAS-CONF-2017-029