PERFORMANCE OF THE ATLAS TAU TRIGGER IN RUN 2

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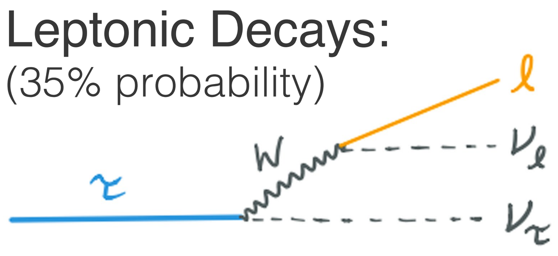
1. Hadronic tau decay modes

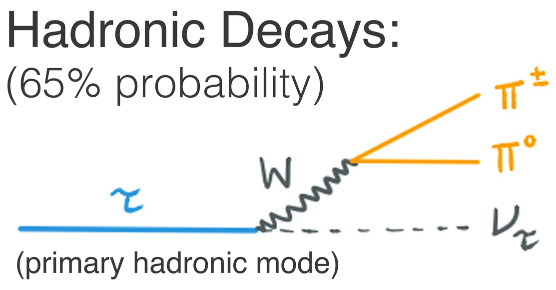
As the heaviest lepton (1.77 GeV), the tau is central to the ATLAS physics program in Run 2 at CERN's Large Hadron Collider. It couples strongly to the SM Higgs boson and could potentially provide access to beyond-the-Standard-Model Higgs partners or other new particles.

Due to its brief lifetime of ~3×10^{-13} seconds, however, the tau usually decays before reaching the detector. Its leptonic decays are detected with the ATLAS leptonic triggers, leaving the tau trigger to focus exclusively on its hadronic decays. The tau's primary hadronic decay modes consist of 1 or 3 charged hadrons such as pions or kaons as well as potentially one or more neutral hadrons.

Leptonic Decays:
(35% probability)



Hadronic Decays:
(65% probability)



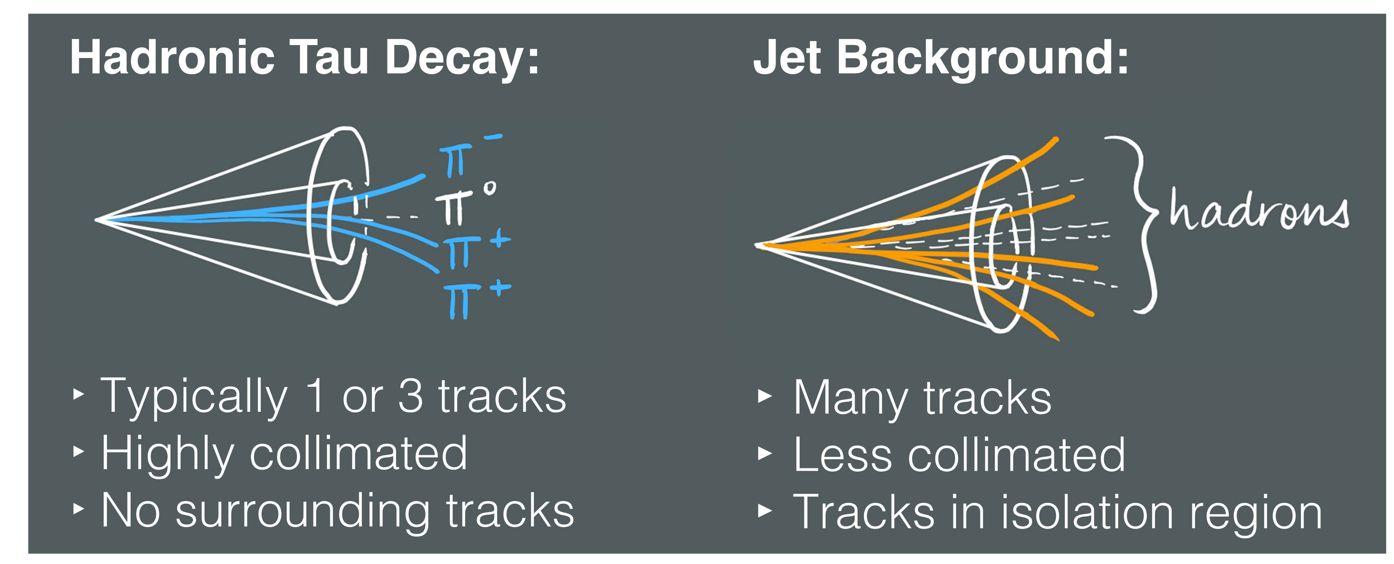
(primary hadronic mode)

Hadronic modes

$\pi^- \pi^0 \nu_\tau$	26%
$\pi^- \nu_\tau$	11%
$\pi^- 2\pi^0 \nu_\tau$	9%
$\pi^+ 2\pi^- \nu_\tau$	9%
Other modes	10%

2. Triggering on taus

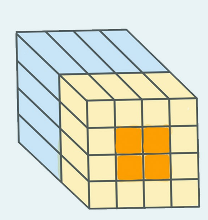
The ATLAS tau trigger is optimized to perform the difficult task of separating hadronic tau decays from high-rate quark- or gluon-initiated jet backgrounds. Quark-initiated jets, in particular, tend to be more collimated and have fewer tracks than gluon-initiated jets, meaning they more closely resemble hadronic tau decays.



Hadronic tau decays mainly feature track multiplicities of 1 or 3 in the core region and no tracks in the isolation region surrounding the core. Quark- and gluon-initiated jets, on the other hand, can feature many tracks with a more even distribution.

3. Tau trigger algorithms & selections

LHC collision rate: 40 MHz



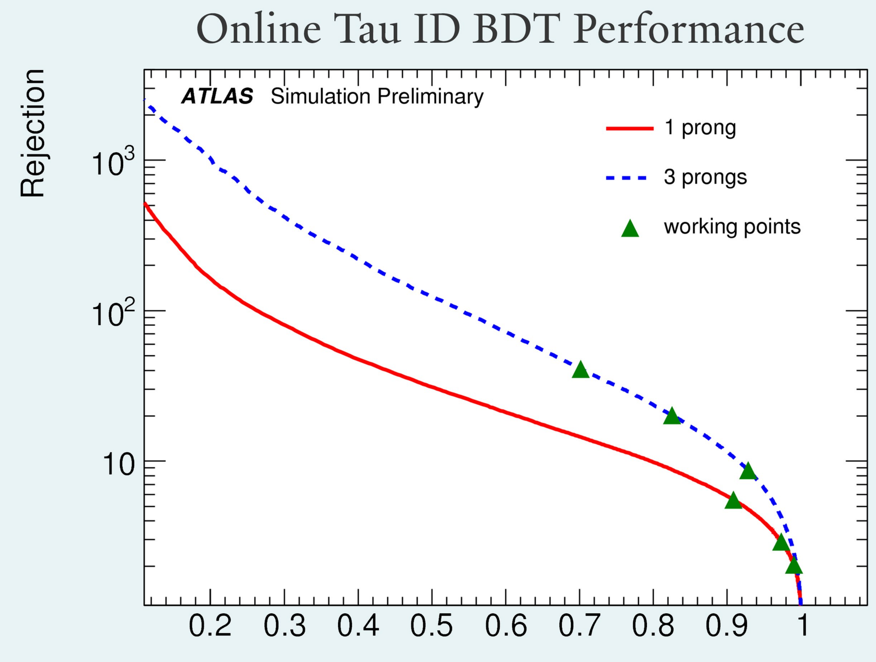
Region-of-interest in calorimeter towers

Hardware (Level 1 Trigger): 100 kHz

- Identifies regions of interest (RoIs) from calorimeters and muon spectrometers
- Sets minimum E_T for the tau candidate
- Makes energy-dependent cut on maximum E_T in the isolation ring
- FPGA-based topological trigger (L1TOPO) makes geometric or kinematic selections
  - e.g. optional cut on the angular separation (ΔR) between taus in a ditau event
- Latency: < 2.5 μs

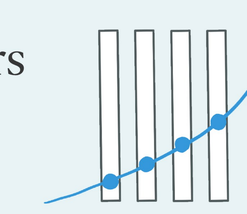
HLT tau trigger step	Mean [ms]	RMS [ms]
Calo-only preselection:		
Topo-clustering	7	3
$\tau_{\text{had-vis}}$ reconstruction	1	0
Track preselection:		
First stage fast tracking	32	16
Second stage fast tracking	27	14
$\tau_{\text{had-vis}}$ reconstruction	1	0
Offline-like selection:		
Precision tracking	21	12
$\tau_{\text{had-vis}}$ reconstruction and BDT	1	0

Online Tau ID BDT Performance



Software (High-Level Trigger): 1 kHz

- Calo-only preselection:
  - Groups calorimeter cells within RoIs into clusters
  - Cuts on minimum p_T for the tau candidate
- Track preselection:
  - Fast track fit with pattern recognition algorithms seeds precision track fitting
  - NTracks cut: only passes tau candidates with between 1 & 3 tracks in the core region (ΔR < 0.2) and ≤ 1 track in the isolation region (0.2 < ΔR < 0.4)
- Offline-like selection:
  - Passes 13 tau identification variables into an offline-like Boosted Decision Tree
  - Assigns the tau candidate a score from 0 to 1, reflecting more jet-like or hadronic tau-like objects

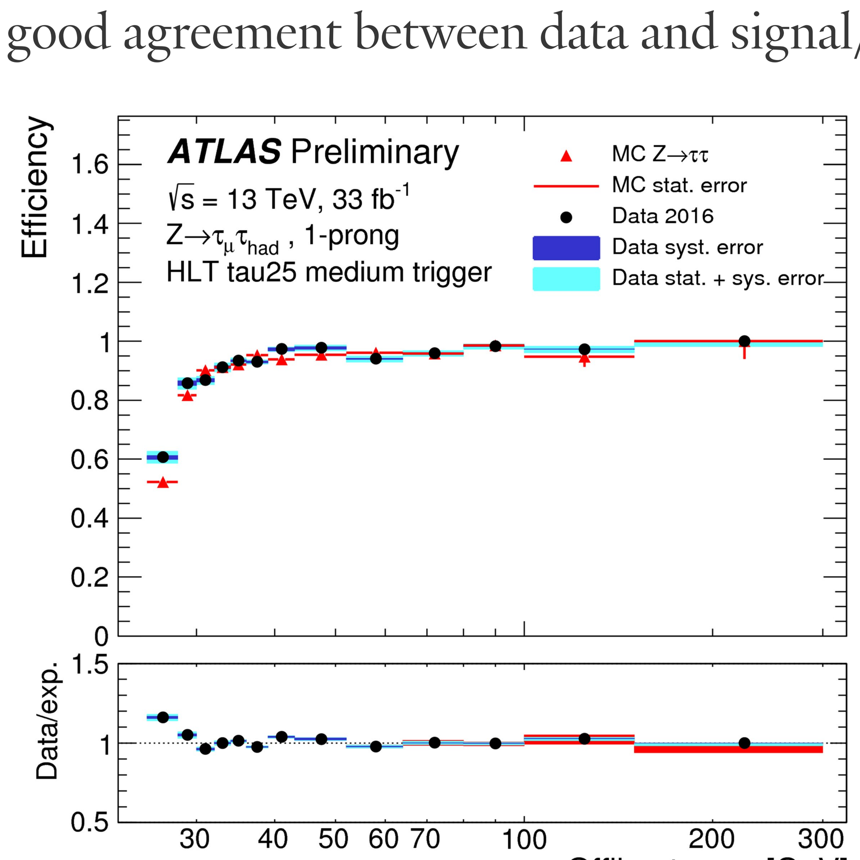


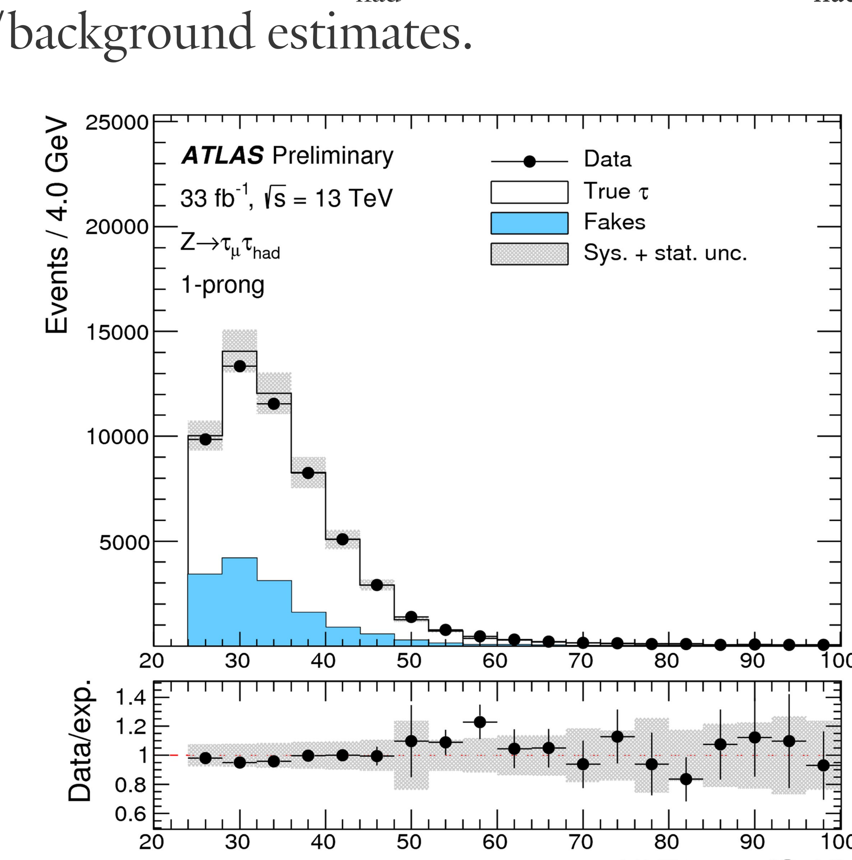
Offline-like precision helical track fitting

The current two-step fast tracking will improve significantly in timing and CPU performance with the implementation of the Fast TracKer (FTK), a new hardware feature that uses lookup tables stored in custom associative memory chips for the pattern recognition. Installation of the FTK system is currently underway, with full commissioning expected in 2017.

4. Menu and performance in Run 2

The tau trigger efficiency is measured using the "tag-and-probe" method. A reconstructed muon candidate that passes the muon trigger serves as the "tag," and an oppositely-charged hadronic tau candidate serves as the "probe." Tag-and-probe selection using $Z\rightarrow\mu\tau_{had}3\nu$ and $tt\rightarrow[b\mu\nu][b\tau_{had}2\nu]$ events shows good agreement between data and signal/background estimates.





FAR LEFT: Tau probes passing requirements including a 25 GeV minimum p_T cut at the HLT reveal a plateau efficiency of 95% for 1-prong (shown) and 85% for 3-prong events.

LEFT: Kinematic distributions of online hadronic tau candidates matched to offline tau probes show good agreement with data.

Trigger	Typical offline selection	Trigger selection L1	Trigger selection HLT	Trigger rate at 1.2×10^{34} cm^{-2}s^{-1} L1 [kHz]	Trigger rate at 1.2×10^{34} cm^{-2}s^{-1} HLT [Hz]
τ	$p_T^\tau > 170$ GeV	60	160	5.2	15
2τ	$p_T^\tau > 40, 30$ GeV, $p_T^{jet} > 80$ GeV	20i,12i,25	35,25,-	6.7	35
τ+e	isolated e, $p_T^e > 18$ GeV, $p_T^\tau > 30$ GeV, $p_T^{jet} > 80$ GeV	15i,12i,25	17i,25,-	3.4	9
$\tau+\mu$	isolated μ, $p_T^\mu > 15$ GeV, $p_T^\tau > 30$ GeV, $p_T^{jet} > 80$ GeV	10,12i,25	14i,25,-	1.7	7
$\tau+E_T^{miss}$	$p_T^\tau > 40$ GeV, $E_T^{miss} > 150$ GeV, $p_T^{jet} > 70$ GeV	20i,45,20	35,70,-	1.8	8
2τ with L1Topo	$p_T^\tau > 40, 30$ GeV, $\Delta R(\tau,\tau) < 2.6$	20i,12i,2.9	35,25,-	5.9	39
2τ with L1Topo	$p_T^\tau > 40, 30$ GeV, $\Delta R(\tau,\tau) < 2.6$, $p_T^{jet} > 80$ GeV	20i,12i,2.9,25	35,25,-,-	3.8	24

The primary 2016 tau triggers are listed in the table above along with their selection requirements and trigger rates. A jet candidate requirement is included to further reduce rates at Level 1 only. The L1Topo triggers were newly commissioned in 2016. Due to its high pT threshold, the single-τ trigger has a minimal μ-dependence, while the combined triggers exhibit moderate μ-dependences.

Further information:

http://cds.cern.ch/record/2274201/files/ATLAS-CONF-2017-061.pdf
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TauTriggerPublicResults

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