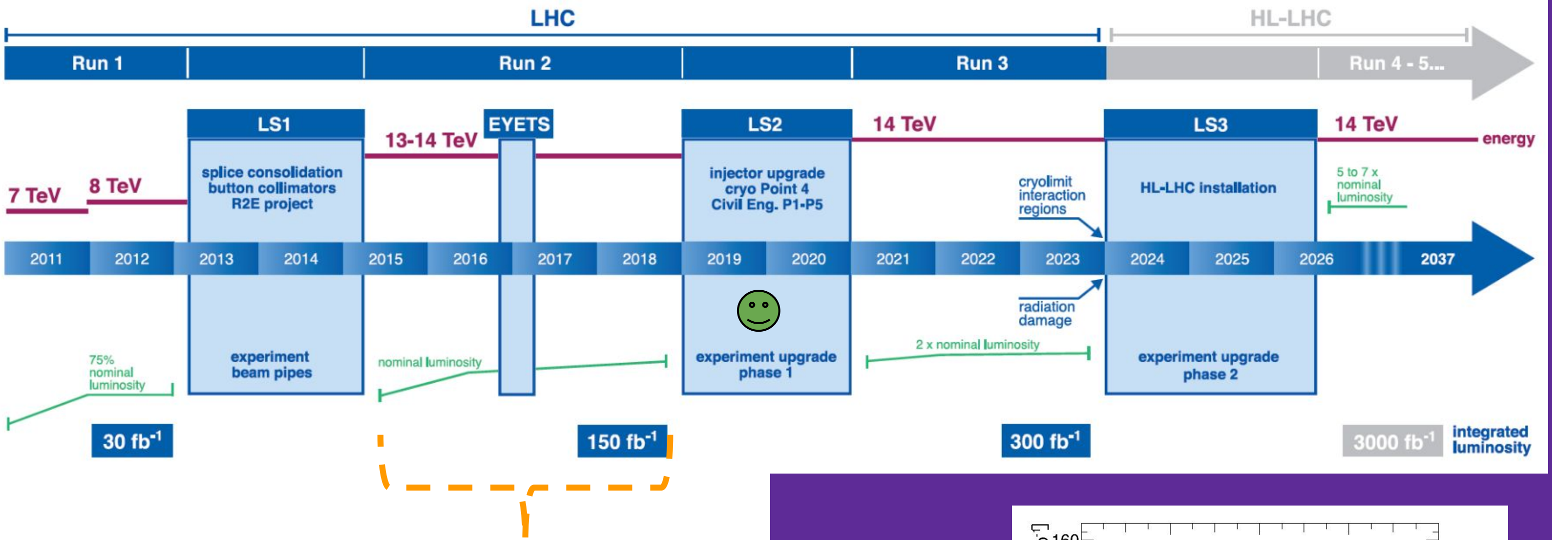
Guillermo Hamity
Taus and Triggers

Thursday 21st Nov 2019

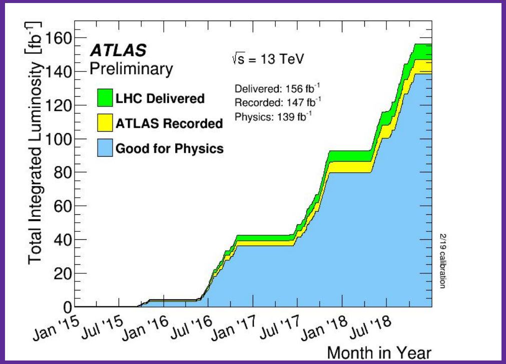
Guillermo Hamity, Sinead Farrington, Andreas Sogaard, Victoria Parrish, Estifa'a Zaid

guillermo.hamity@cern.ch

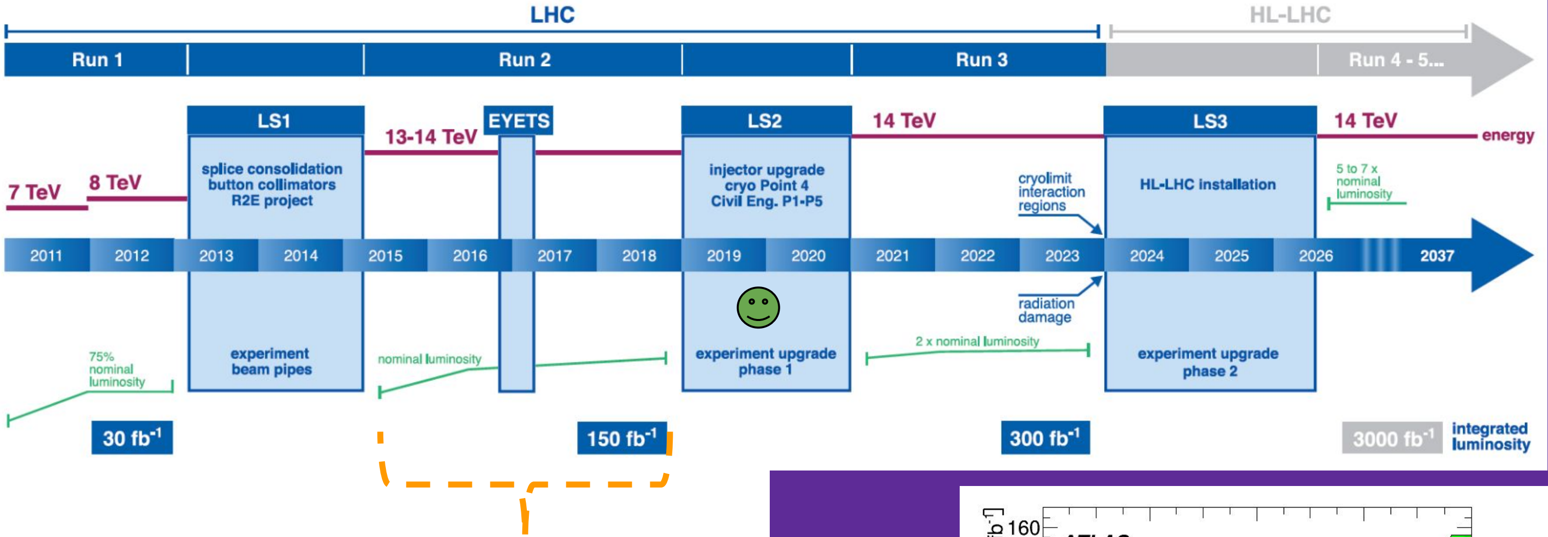
Setting the scene



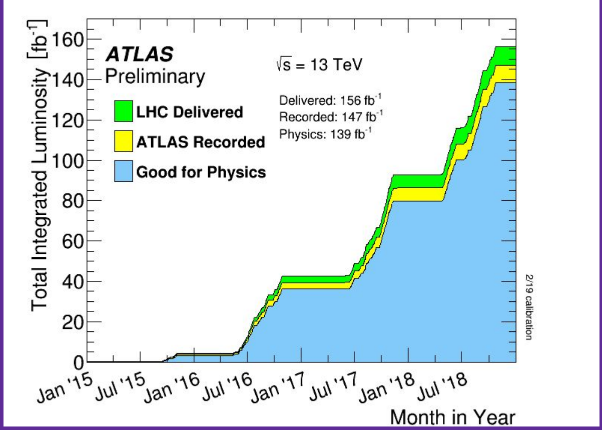
- Talk focused around Run-II hardware and techniques
  - Not much content public for Run-III
  - Run-III is in deep R&D so developing and changing very quickly
    (talk is probably already outdated!)



Setting the scene



- Also, Run-II provides 150/fb of data
- “unexplored” in displaced taus
- **Online:** Triggers have already fired, but some acceptance may be accessible for displaced taus
- **Offline:** Tau reconstruction/ID can be re-run/tuned
- Excellent time to think about what we want in Run-III

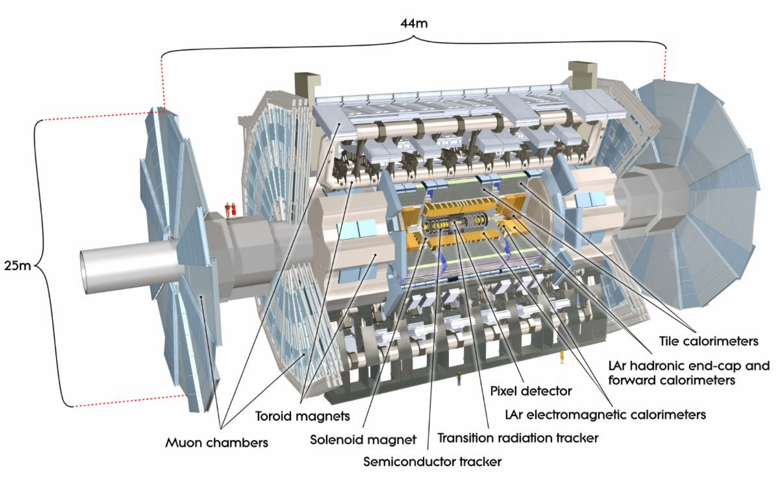


Overview

- ATLAS Trigger
  - Run-II TDAQ and Trigger Menu
  - What Run-III will bring (limited)
- Tau Leptons
  - Reconstruction/Identification
  - Triggers
  - Calibration
- Tau Analysis for LLPs (considerations)

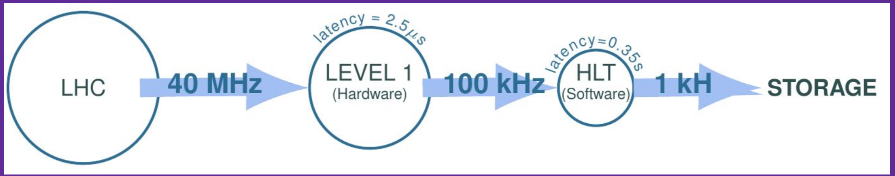
Trigger and Data Acquisition (TDAQ)

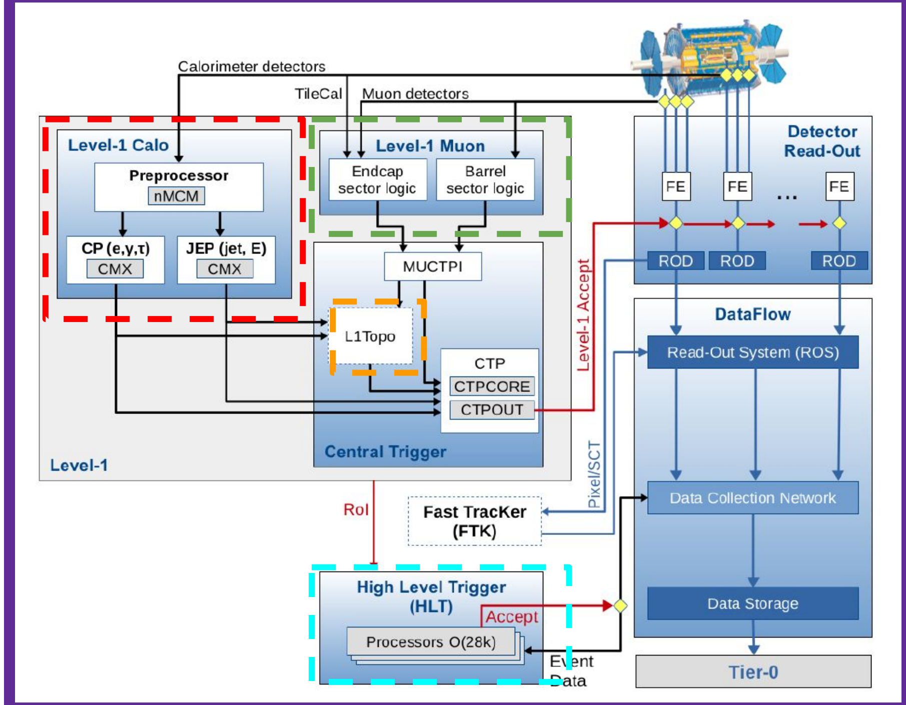
ATLAS Trigger Overview



ATLAS Detector 140M Readout channels
TDAQ two stage process:

- Level-1 trigger (hardware)
  100 kHz (240 GB/s) in Run-II
  - L1Calo
  - L1Muon
- High-Level trigger (software)
  1 kHz (2.4 GB/s)





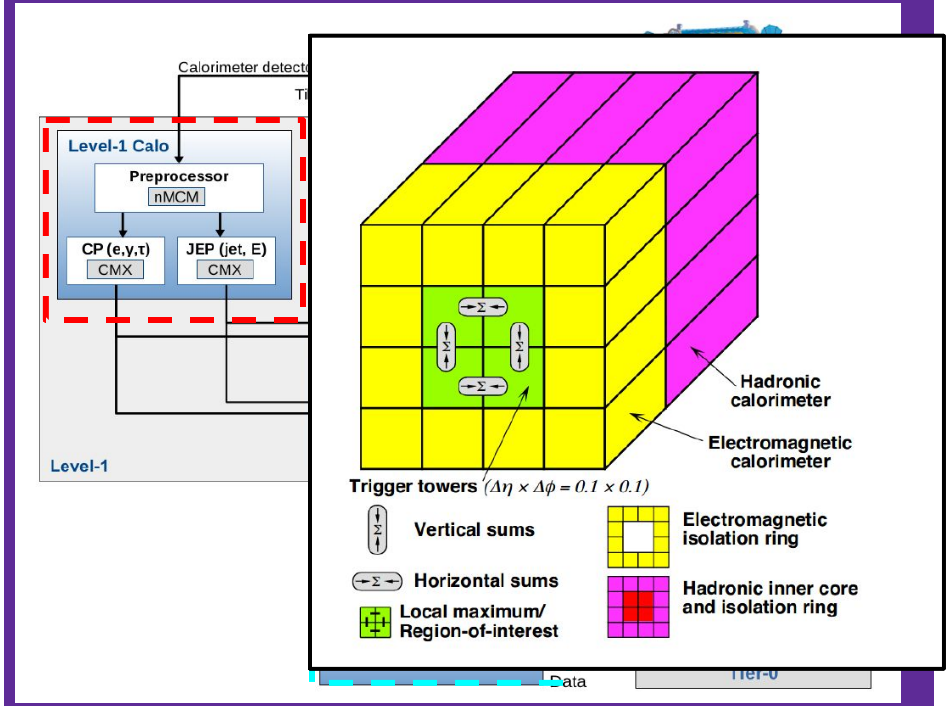
Level-1

L1-Calorimeter trigger is seeded by analogue signals from ~7K trigger towers ($\phi \times \eta = 0.1 \times 0.1$)
Seed Clustering and Jet/Energy processors

- Clustering Processor
  - Used for L1 objects (ele,gam,taus)
  - **RoI** from 2x2 trigger towers in EM-Cal
  - Surrounded by Isolation and Hadronic regions
- Jet/Energy processor
  - **RoI** as 4×4 or 8×8 trigger tower clusters
  - Used to seed jet triggers and calculate the global $\sum$ E used in miss ET triggers.

L1-Muon trigger seeded by triggering chambers in Muon Spectrometer

L1Topological trigger introduced in RunII
- Combines kinematics and geometric information driven by physics-based signatures
  - Ele, gamma, tau, jets, MET



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L1-Muon trigger seeded by triggering chambers in Muon Spectrometer

L1Topological trigger introduced in RunII

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L1Topo (Some numbers)
Input: lists of trigger objects (TOBs)

120 e, 120 τ, 32μ, 64 jets, MET

Inputs limited by bandwidth

E.g. EM objects (ele,gamma,tau)
Energy (8 bits): 0.5 or 1 GeV resolution
Isolation (5 bits): EM and HAD around 2x2 tower core
Position (6η + 6ϕ bits) , 0.1 granularity (η x ϕ): |η|<2.5

Algorithms

(list not exhaustive)

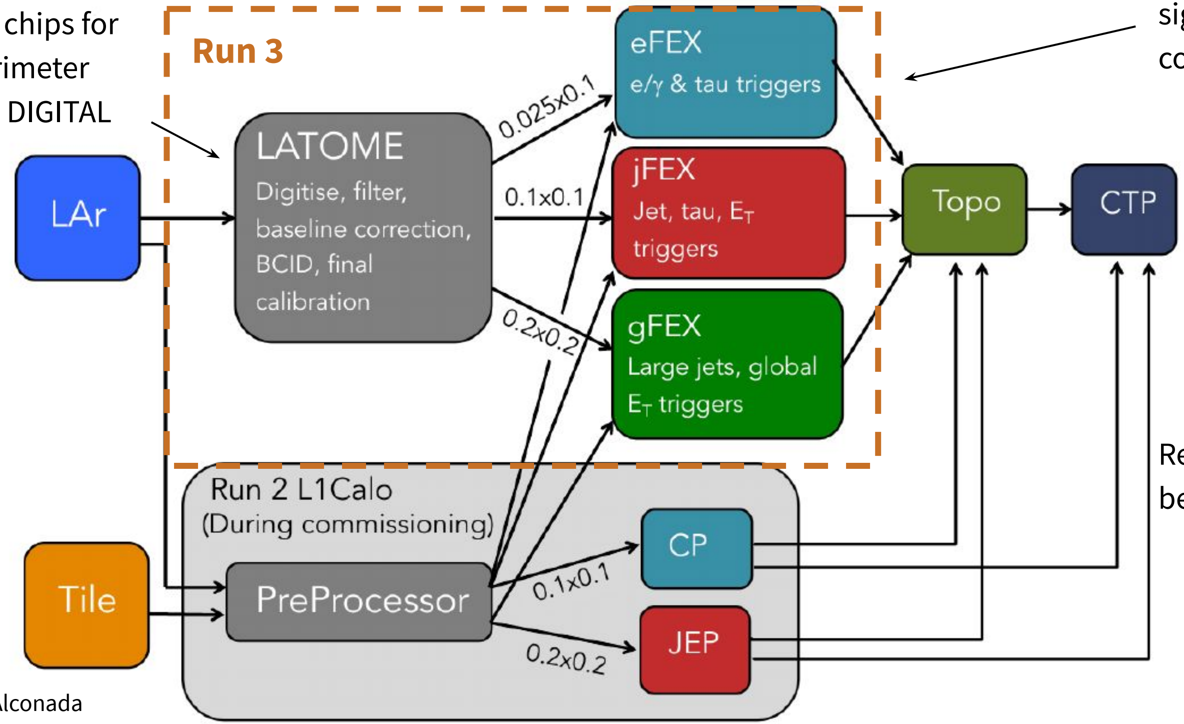
Sorting by E or E_T ATL-DAQ-PROC-2017-002.pdf

Type	Name	Details
Angular Separation	$\Delta\phi$	$\Delta\phi(\mathrm{TOB}_1, \mathrm{TOB}_2)$
	$\Delta\eta$	$\Delta\eta(\mathrm{TOB}_1, \mathrm{TOB}_2)$
	ΔR	$\sqrt{\Delta\phi^2 + \Delta\eta^2}$
Invariant Mass	M	$\sqrt{E_T^1 E_T^2(\cosh\Delta\eta - \cos\Delta\phi)}$
Transverse Mass	M_T	$\sqrt{E_T E_T^{miss}(1 - \cos\Delta\phi)}$
Interaction hardness	H_T	$\Sigma p_T(\mathrm{jets})$

ƎE

Level-1 Calo Upgrade (Simplified)

Phase-I Upgrade
Readout chips for LAr calorimeter provides DIGITAL signal



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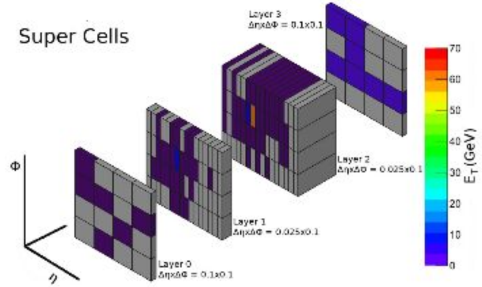
Feature Extractor (FEX) boards significant increase in algorithm complexity and calo read-out granularity

70 GeV e⁻ with finer granularity



Resolution improvement translates to better turn-on at pT thresholds

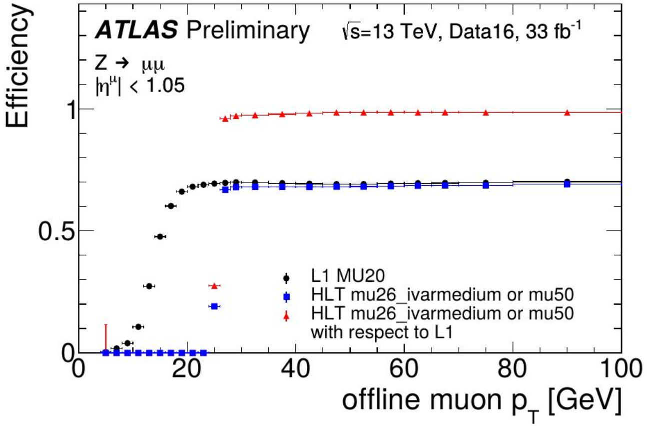
L1Topo also receives additional processing upgrade:

Run2 : 120 e, 120 τ, 32μ 64 jets, MET — precision (ET,η,φ)~ 0.5 GeV, 0.1, 0.1

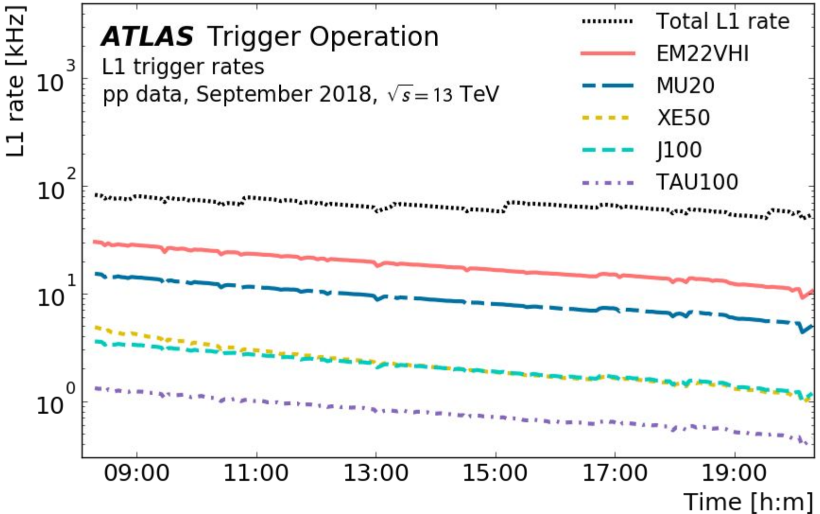
Run3 *Expected*: 144-288 e, 144-288 τ, 32μ, 192-336 jets — precision (ET,η,φ)~ 100-200 MeV, 0.025, 0.1

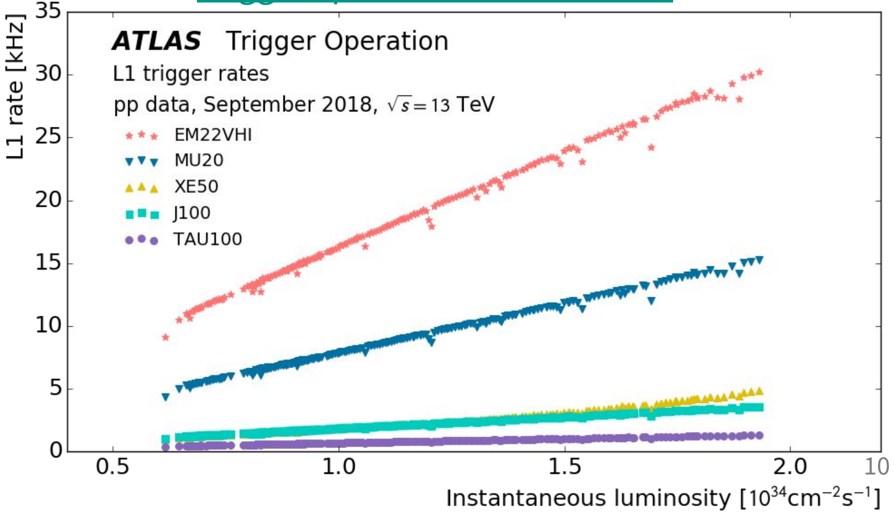
High-Level Trigger

- High-Level Triggers algorithms mimic offline reconstruction methods (0.35s)
- Avoiding pre-scales requires
    - Higher pT thresholds of L1/HLT objects
    - Combining multiple triggers



[TriggerOperationPublicResults]





2018

Trigger Menu

- This is very dependant on run conditions
- Triggers have variations, e.g., different working points, isolation requirements etc.
- Nominal object triggers and not an exhaustive list

Trigger	Typical offline selection	Trigger Selection		Level-1 Peak Rate (kHz)	HLT Peak Rate (Hz)
		Level-1 (GeV)	HLT (GeV)	$L = 1.7 \times 10^{34}$ cm^{-2}s^{-1}	
Single leptons	Single isolated μ, $p_T > 27$ GeV	20	26 (i)	15	180
	Single isolated tight e, $p_T > 27$ GeV	22 (i)	26 (i)	28	180
	Single μ, $p_T > 52$ GeV	20	50	15	61
	Single e, $p_T > 61$ GeV	22 (i)	60	28	18
	Single τ, $p_T > 170$ GeV	100	160	1.2	47
Two leptons	Two μ, each $p_T > 15$ GeV	2×10	2×14	1.8	26
	Two μ, $p_T > 23, 9$ GeV	20	22, 8	15	42
	Two very loose e, each $p_T > 18$ GeV	2×15 (i)	2×17	1.7	12
	One e & one μ, $p_T > 8, 25$ GeV	20 (μ)	7, 24	15	5
	One e & one μ, $p_T > 18, 15$ GeV	15, 10	17, 14	2.0	4
	One e & one μ, $p_T > 27, 9$ GeV	22 (e, i)	26, 8	28	3
	Two τ, $p_T > 40, 30$ GeV	20 (i), 12 (i) (+jets, topo)	35, 25	5	61
	One τ & one isolated μ, $p_T > 30, 15$ GeV	12 (i), 10 (+jets)	25, 14 (i)	2.1	10
	One τ & one isolated e, $p_T > 30, 18$ GeV	12 (i), 15 (i) (+jets)	25, 17 (i)	4	15
Three leptons	Three loose e, $p_T > 25, 13, 13$ GeV	$20, 2 \times 10$	$24, 2 \times 12$	1.3	< 0.1
	Three μ, each $p_T > 7$ GeV	3×6	3×6	0.2	6
	Three μ, $p_T > 21, 2 \times 5$ GeV	20	$20, 2 \times 4$	15	8
	Two μ & one loose e, $p_T > 2 \times 11, 13$ GeV	2×10 (μ)	$2 \times 10, 12$	1.8	0.3
	Two loose e & one μ, $p_T > 2 \times 13, 11$ GeV	$2 \times 8, 10$	$2 \times 12, 10$	1.7	0.1
One photon	One loose γ, $p_T > 145$ GeV	22 (i)	140	28	43
Two photons	Two loose γ, $p_T > 55, 55$ GeV	2×20	50, 50	2.6	6
	Two medium γ, $p_T > 40, 30$ GeV	2×20	35, 25	2.6	17
	Two tight γ, $p_T > 25, 25$ GeV	2×15 (i)	2×20 (i)	1.7	14
Single jet	Jet ($R = 0.4$), $p_T > 435$ GeV	100	420	3.3	33
	Jet ($R = 1.0$), $p_T > 480$ GeV	100	460	3.3	24
	Jet ($R = 1.0$), $p_T > 450$ GeV, $m_{jet} > 50$ GeV	100	420, $m_{jet} > 40$	3.3	29
E_T^{miss}	$E_T^{miss} > 200$ GeV	50	110	5	110
Multi-jets	Four jets, each $p_T > 125$ GeV	3×50	4×115	0.5	16
	Five jets, each $p_T > 95$ GeV	4×15	5×85	5	10
	Six jets, each $p_T > 80$ GeV	4×15	6×70	5	4
	Six jets, each $p_T > 60$ GeV, $\lvert\eta\rvert < 2.0$	4×15	6×55, $\lvert\eta\rvert < 2.4$	5	15
b–jets	One b ($\epsilon = 40\%$), $p_T > 235$ GeV	100	225	3.3	15
	Two b ($\epsilon = 60\%$), $p_T > 185, 70$ GeV	100	175, 60	3.3	12
	One b ($\epsilon = 40\%$) & three jets, each $p_T > 85$ GeV	4×15	4×75	5	15
	Two b ($\epsilon = 70\%$) & one jet, $p_T > 65, 65, 160$ GeV	$2 \times 30, 85$	$2 \times 55, 150$	1.2	15
	Two b ($\epsilon = 60\%$) & two jets, each $p_T > 65$ GeV	4×15, $\lvert\eta\rvert < 2.5$	4×55	3.2	13
B-Physics	Two μ, $p_T > 11, 6$ GeV	11, 6	11, 6 (di-μ)	2.5	47
	Two μ, $p_T > 6, 6$ GeV, $2.5 < m(\mu,\mu) < 4.0$ GeV	2×6 (J/ψ, topo)	2×6 (J/ψ)	1.6	48
	Two μ, $p_T > 6, 6$ GeV, $4.7 < m(\mu,\mu) < 5.9$ GeV	2×6 (B, topo)	2×6 (B)	1.6	5
	Two μ, $p_T > 6, 6$ GeV, $7 < m(\mu,\mu) < 12$ GeV	2×6 (Υ, topo)	2×6 (Υ)	1.4	10
Total Rate				85	1550

2018

Trigger Menu

Electrons
- Single:
  - Isolated Tight ~27 GeV
  - No isolation ~61GeV
- Di-Electron: ~18GeV
- 3 loose ele: 25, 13, 13 GeV

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	Single e, $p_T > 61$ GeV	22 (i)	60	28	18
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	One e & one μ, $p_T > 8, 25$ GeV	20 (μ)	7, 24	15	5
	One e & one μ, $p_T > 18, 15$ GeV	15, 10	17, 14	2.0	4
	One e & one μ, $p_T > 27, 9$ GeV	22 (e, i)	26, 8	28	3
	Two τ, $p_T > 40, 30$ GeV	20 (i), 12 (i) (+jets, topo)	35, 25	5	61
	One τ & one isolated μ, $p_T > 30, 15$ GeV	12 (i), 10 (+jets)	25, 14 (i)	2.1	10
	One τ & one isolated e, $p_T > 30, 18$ GeV	12 (i), 15 (i) (+jets)	25, 17 (i)	4	15
Three leptons	Three loose e, $p_T > 25, 13, 13$ GeV	20, 2×10	24, 2×12	1.3	< 0.1
	Three μ, each $p_T > 7$ GeV	3×6	3×6	0.2	6
	Three μ, $p_T > 21, 2 \times 5$ GeV	20	20, 2×4	15	8
	Two μ & one loose e, $p_T > 2 \times 11, 13$ GeV	2×10 (μ)	2×10, 12	1.8	0.3
	Two loose e & one μ, $p_T > 2 \times 13, 11$ GeV	2×8, 10	2×12, 10	1.7	0.1
One photon	One loose γ, $p_T > 145$ GeV	22 (i)	140	28	43
Two photons	Two loose γ, $p_T > 55, 55$ GeV	2×20	50, 50	2.6	6
	Two medium γ, $p_T > 40, 30$ GeV	2×20	35, 25	2.6	17
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E_T^{miss}	$E_T^{miss} > 200$ GeV	50	110	5	110
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	Five jets, each $p_T > 95$ GeV	4×15	5×85	5	10
	Six jets, each $p_T > 80$ GeV	4×15	6×70	5	4
	Six jets, each $p_T > 60$ GeV, $\lvert\eta\rvert < 2.0$	4×15	6×55, $\lvert\eta\rvert < 2.4$	5	15
b-jets	One b ($\epsilon = 40\%$), $p_T > 235$ GeV	100	225	3.3	15
	Two b ($\epsilon = 60\%$), $p_T > 185, 70$ GeV	100	175, 60	3.3	12
	One b ($\epsilon = 40\%$) & three jets, each $p_T > 85$ GeV	4×15	4×75	5	15
	Two b ($\epsilon = 70\%$) & one jet, $p_T > 65, 65, 160$ GeV	2×30, 85	2×55, 150	1.2	15
	Two b ($\epsilon = 60\%$) & two jets, each $p_T > 65$ GeV	4×15, $\lvert\eta\rvert < 2.5$	4×55	3.2	13
B-Physics	Two μ, $p_T > 11, 6$ GeV	11, 6	11, 6 (di-μ)	2.5	47
	Two μ, $p_T > 6, 6$ GeV, $2.5 < m(\mu,\mu) < 4.0$ GeV	2×6 (J/ψ, topo)	2×6 (J/ψ)	1.6	48
	Two μ, $p_T > 6, 6$ GeV, $4.7 < m(\mu,\mu) < 5.9$ GeV	2×6 (B, topo)	2×6 (B)	1.6	5
	Two μ, $p_T > 6, 6$ GeV, $7 < m(\mu,\mu) < 12$ GeV	2×6 (Υ, topo)	2×6 (Υ)	1.4	10
Total Rate				85	1550

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Trigger Menu

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Muons

- Single: ~27 GeV
- Di-Mu: ~23, 9 GeV

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	Single μ, $p_T > 52$ GeV	20	50	15	61
	Single e, $p_T > 61$ GeV	22 (i)	60	28	18
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Photons

- Single: ~145 GeV
- Di-Gam: ~55, 55 GeV

Trigger	Typical offline selection	Trigger Selection: Level-1 (GeV)	Trigger Selection: HLT (GeV)	Level-1 Peak Rate (kHz) $L = 1.7 \times 10^{34}$ cm^{-2}s^{-1}	HLT Peak Rate (Hz) $L = 1.7 \times 10^{34}$ cm^{-2}s^{-1}
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	One τ & one isolated μ, $p_T > 30, 15$ GeV	12 (i), 10 (+jets)	25, 14 (i)	2.1	10
	One τ & one isolated e, $p_T > 30, 18$ GeV	12 (i), 15 (i) (+jets)	25, 17 (i)	4	15
Three leptons	Three loose e, $p_T > 25, 13, 13$ GeV	20, 2×10	24, 2×12	1.3	< 0.1
	Three μ, each $p_T > 7$ GeV	3×6	3×6	0.2	6
	Three μ, $p_T > 21, 2\times5$ GeV	20	20, 2×4	15	8
	Two μ & one loose e, $p_T > 2\times11, 13$ GeV	2×10 (μ)	2×10, 12	1.8	0.3
	Two loose e & one μ, $p_T > 2\times13, 11$ GeV	2×8, 10	2×12, 10	1.7	0.1
One photon	One loose γ, $p_T > 145$ GeV	22 (i)	140	28	43
Two photons	Two loose γ, $p_T > 55, 55$ GeV	2×20	50, 50	2.6	6
	Two medium γ, $p_T > 40, 30$ GeV	2×20	35, 25	2.6	17
	Two tight γ, $p_T > 25, 25$ GeV	2×15 (i)	2×20 (i)	1.7	14
Single jet	Jet ($R = 0.4$), $p_T > 435$ GeV	100	420	3.3	33
	Jet ($R = 1.0$), $p_T > 480$ GeV	100	460	3.3	24
	Jet ($R = 1.0$), $p_T > 450$ GeV, $m_{jet} > 50$ GeV	100	420, $m_{jet} > 40$	3.3	29
E_T^{miss}	$E_T^{miss} > 200$ GeV	50	110	5	110
Multi-jets	Four jets, each $p_T > 125$ GeV	3×50	4×115	0.5	16
	Five jets, each $p_T > 95$ GeV	4×15	5×85	5	10
	Six jets, each $p_T > 80$ GeV	4×15	6×70	5	4
	Six jets, each $p_T > 60$ GeV, $\lvert\eta\rvert < 2.0$	4×15	6×55, $\lvert\eta\rvert < 2.4$	5	15
b−jets	One b ($\epsilon = 40\%$), $p_T > 235$ GeV	100	225	3.3	15
	Two b ($\epsilon = 60\%$), $p_T > 185, 70$ GeV	100	175, 60	3.3	12
	One b ($\epsilon = 40\%$) & three jets, each $p_T > 85$ GeV	4×15	4×75	5	15
	Two b ($\epsilon = 70\%$) & one jet, $p_T > 65, 65, 160$ GeV	2×30, 85	2×55, 150	1.2	15
	Two b ($\epsilon = 60\%$) & two jets, each $p_T > 65$ GeV	4×15, $\lvert\eta\rvert < 2.5$	4×55	3.2	13
B-Physics	Two μ, $p_T > 11, 6$ GeV	11, 6	11, 6 (di-μ)	2.5	47
	Two μ, $p_T > 6, 6$ GeV, $2.5 < m(\mu,\mu) < 4.0$ GeV	2×6 (J/ψ, topo)	2×6 (J/ψ)	1.6	48
	Two μ, $p_T > 6, 6$ GeV, $4.7 < m(\mu,\mu) < 5.9$ GeV	2×6 (B, topo)	2×6 (B)	1.6	5
	Two μ, $p_T > 6, 6$ GeV, $7 < m(\mu,\mu) < 12$ GeV	2×6 (Υ, topo)	2×6 (Υ)	1.4	10
Total Rate				85	1550

2018

Trigger Menu

Jets
- Single: 435 GeV
- 4 Jets: 125 GeV

b-Jets
- Dependant on working point
  - 2 b's: 185, 70 GeV

MET: 200 GeV

Trigger	Typical offline selection	Trigger Selection		Level-1 Peak Rate (kHz)	HLT Peak Rate (Hz)
		Level-1 (GeV)	HLT (GeV)	$L = 1.7 \times 10^{34}$ cm^{-2}s^{-1}	
Single leptons	Single isolated μ, $p_T > 27$ GeV	20	26 (i)	15	180
	Single isolated tight e, $p_T > 27$ GeV	22 (i)	26 (i)	28	180
	Single μ, $p_T > 52$ GeV	20	50	15	61
	Single e, $p_T > 61$ GeV	22 (i)	60	28	18
	Single τ, $p_T > 170$ GeV	100	160	1.2	47
Two leptons	Two μ, each $p_T > 15$ GeV	2×10	2×14	1.8	26
	Two μ, $p_T > 23, 9$ GeV	20	22, 8	15	42
	Two very loose e, each $p_T > 18$ GeV	2×15 (i)	2×17	1.7	12
	One e & one μ, $p_T > 8, 25$ GeV	20 (μ)	7, 24	15	5
	One e & one μ, $p_T > 18, 15$ GeV	15, 10	17, 14	2.0	4
	One e & one μ, $p_T > 27, 9$ GeV	22 (e, i)	26, 8	28	3
	Two τ, $p_T > 40, 30$ GeV	20 (i), 12 (i) (+jets, topo)	35, 25	5	61
	One τ & one isolated μ, $p_T > 30, 15$ GeV	12 (i), 10 (+jets)	25, 14 (i)	2.1	10
	One τ & one isolated e, $p_T > 30, 18$ GeV	12 (i), 15 (i) (+jets)	25, 17 (i)	4	15
Three leptons	Three loose e, $p_T > 25, 13, 13$ GeV	20, 2×10	24, 2×12	1.3	< 0.1
	Three μ, each $p_T > 7$ GeV	3×6	3×6	0.2	6
	Three μ, $p_T > 21, 2 \times 5$ GeV	20	20, 2×4	15	8
	Two μ & one loose e, $p_T > 2 \times 11, 13$ GeV	2×10 (μ)	2×10, 12	1.8	0.3
	Two loose e & one μ, $p_T > 2 \times 13, 11$ GeV	2×8, 10	2×12, 10	1.7	0.1
One photon	One loose γ, $p_T > 145$ GeV	22 (i)	140	28	43
Two photons	Two loose γ, $p_T > 55, 55$ GeV	2×20	50, 50	2.6	6
	Two medium γ, $p_T > 40, 30$ GeV	2×20	35, 25	2.6	17
	Two tight γ, $p_T > 25, 25$ GeV	2×15 (i)	2×20 (i)	1.7	14
Single jet	Jet ($R = 0.4$), $p_T > 435$ GeV	100	420	3.3	33
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	Jet ($R = 1.0$), $p_T > 450$ GeV, $m_{jet} > 50$ GeV	100	420, $m_{jet} > 40$	3.3	29
E_T^{miss}	$E_T^{miss} > 200$ GeV	50	110	5	110
Multi-jets	Four jets, each $p_T > 125$ GeV	3×50	4×115	0.5	16
	Five jets, each $p_T > 95$ GeV	4×15	5×85	5	10
	Six jets, each $p_T > 80$ GeV	4×15	6×70	5	4
	Six jets, each $p_T > 60$ GeV, $\lvert\eta\rvert < 2.0$	4×15	6×55, $\lvert\eta\rvert < 2.4$	5	15
b–jets	One b ($\epsilon = 40\%$), $p_T > 235$ GeV	100	225	3.3	15
	Two b ($\epsilon = 60\%$), $p_T > 185, 70$ GeV	100	175, 60	3.3	12
	One b ($\epsilon = 40\%$) & three jets, each $p_T > 85$ GeV	4×15	4×75	5	15
	Two b ($\epsilon = 70\%$) & one jet, $p_T > 65, 65, 160$ GeV	2×30, 85	2×55, 150	1.2	15
	Two b ($\epsilon = 60\%$) & two jets, each $p_T > 65$ GeV	4×15, $\lvert\eta\rvert < 2.5$	4×55	3.2	13
B-Physics	Two μ, $p_T > 11, 6$ GeV	11, 6	11, 6 (di-μ)	2.5	47
	Two μ, $p_T > 6, 6$ GeV, $2.5 < m(\mu,\mu) < 4.0$ GeV	2×6 (J/ψ, topo)	2×6 (J/ψ)	1.6	48
	Two μ, $p_T > 6, 6$ GeV, $4.7 < m(\mu,\mu) < 5.9$ GeV	2×6 (B, topo)	2×6 (B)	1.6	5
	Two μ, $p_T > 6, 6$ GeV, $7 < m(\mu,\mu) < 12$ GeV	2×6 (Υ, topo)	2×6 (Υ)	1.4	10
Total Rate				85	1550

2018

Trigger Menu

Jets
- Single: 435 GeV
- 4 Jets: 125GeV

b-Jets
- Dependant on working point
  - 2 b's: 185, 70 GeV

MET: 200 GeV

Will discuss tau triggers later

Trigger	Typical offline selection	Trigger Selection		Level-1 Peak Rate (kHz)	HLT Peak Rate (Hz)
		Level-1 (GeV)	HLT (GeV)	$L = 1.7 \times 10^{34}$ cm^{-2}s^{-1}	
Single leptons	Single isolated μ, $p_T > 27$ GeV	20	26 (i)	15	180
	Single isolated tight e, $p_T > 27$ GeV	22 (i)	26 (i)	28	180
	Single μ, $p_T > 52$ GeV	20	50	15	61
	Single e, $p_T > 61$ GeV	22 (i)	60	28	18
	Single τ, $p_T > 170$ GeV	100	160	1.2	47
Two leptons	Two μ, each $p_T > 15$ GeV	2×10	2×14	1.8	26
	Two μ, $p_T > 23, 9$ GeV	20	22, 8	15	42
	Two very loose e, each $p_T > 18$ GeV	2×15 (i)	2×17	1.7	12
	One e & one μ, $p_T > 8, 25$ GeV	20 (μ)	7, 24	15	5
	One e & one μ, $p_T > 18, 15$ GeV	15, 10	17, 14	2.0	4
	One e & one μ, $p_T > 27, 9$ GeV	22 (e, i)	26, 8	28	3
	Two τ, $p_T > 40, 30$ GeV	20 (i), 12 (i) (+jets, topo)	35, 25	5	61
	One τ & one isolated μ, $p_T > 30, 15$ GeV	12 (i), 10 (+jets)	25, 14 (i)	2.1	10
	One τ & one isolated e, $p_T > 30, 18$ GeV	12 (i), 15 (i) (+jets)	25, 17 (i)	4	15
Three leptons	Three loose e, $p_T > 25, 13, 13$ GeV	$20, 2 \times 10$	$24, 2 \times 12$	1.3	< 0.1
	Three μ, each $p_T > 7$ GeV	3×6	3×6	0.2	6
	Three μ, $p_T > 21, 2 \times 5$ GeV	20	$20, 2 \times 4$	15	8
	Two μ & one loose e, $p_T > 2 \times 11, 13$ GeV	2×10 (μ)	$2 \times 10, 12$	1.8	0.3
	Two loose e & one μ, $p_T > 2 \times 13, 11$ GeV	$2 \times 8, 10$	$2 \times 12, 10$	1.7	0.1
One photon	One loose γ, $p_T > 145$ GeV	22 (i)	140	28	43
Two photons	Two loose γ, $p_T > 55, 55$ GeV	2×20	50, 50	2.6	6
	Two medium γ, $p_T > 40, 30$ GeV	2×20	35, 25	2.6	17
	Two tight γ, $p_T > 25, 25$ GeV	2×15 (i)	2×20 (i)	1.7	14
Single jet	Jet ($R = 0.4$), $p_T > 435$ GeV	100	420	3.3	33
	Jet ($R = 1.0$), $p_T > 480$ GeV	100	460	3.3	24
	Jet ($R = 1.0$), $p_T > 450$ GeV, $m_{jet} > 50$ GeV	100	420, $m_{jet} > 40$	3.3	29
E_T^{miss}	$E_T^{miss} > 200$ GeV	50	110	5	110
Multi-jets	Four jets, each $p_T > 125$ GeV	3×50	4×115	0.5	16
	Five jets, each $p_T > 95$ GeV	4×15	5×85	5	10
	Six jets, each $p_T > 80$ GeV	4×15	6×70	5	4
	Six jets, each $p_T > 60$ GeV, $\|\eta\| < 2.0$	4×15	6×55, $\|\eta\| < 2.4$	5	15
b-jets	One b ($\epsilon = 40\%$), $p_T > 235$ GeV	100	225	3.3	15
	Two b ($\epsilon = 60\%$), $p_T > 185, 70$ GeV	100	175, 60	3.3	12
	One b ($\epsilon = 40\%$) & three jets, each $p_T > 85$ GeV	4×15	4×75	5	15
	Two b ($\epsilon = 70\%$) & one jet, $p_T > 65, 65, 160$ GeV	$2 \times 30, 85$	$2 \times 55, 150$	1.2	15
	Two b ($\epsilon = 60\%$) & two jets, each $p_T > 65$ GeV	4×15, $\|\eta\| < 2.5$	4×55	3.2	13
B-Physics	Two μ, $p_T > 11, 6$ GeV	11, 6	11, 6 (di-μ)	2.5	47
	Two μ, $p_T > 6, 6$ GeV, $2.5 < m(\mu,\mu) < 4.0$ GeV	2×6 (J/ψ, topo)	2×6 (J/ψ)	1.6	48
	Two μ, $p_T > 6, 6$ GeV, $4.7 < m(\mu,\mu) < 5.9$ GeV	2×6 (B, topo)	2×6 (B)	1.6	5
	Two μ, $p_T > 6, 6$ GeV, $7 < m(\mu,\mu) < 12$ GeV	2×6 (Υ, topo)	2×6 (Υ)	1.4	10
Total Rate				85	1550

2018
Trigger Menu

LLP searches

Many searches use nominal triggers, others have specific triggers

DiLepton:

- Displaced electrons triggered with photon triggers
  - 1 gamma (~150-200 GeV) or 2 gamma (~50 GeV)
- Displaced muons (muon trigger without ID tracks) ~80 GeV

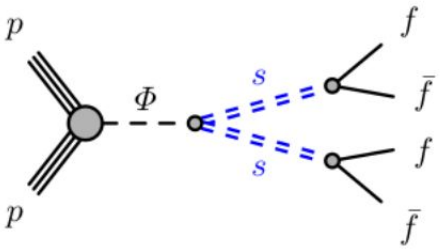
DV: MET (200GeV), Photon (target ele), Muon (no ID hits), multi-jets (different multiplicities)

CalRatio: Specifically designed for signature (next slide)

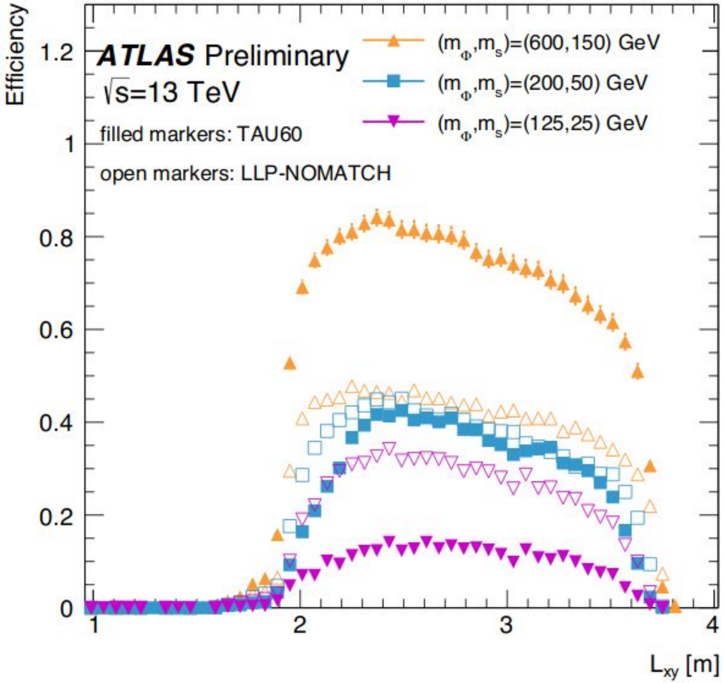
VH or HNL? Can trigger on associated leptons directly

Trigger	Typical offline selection	Trigger Selection: Level-1 (GeV)	Trigger Selection: HLT (GeV)	Level-1 Peak Rate (kHz) $L = 1.7 \times 10^{34}$ cm^{-2}s^{-1}	HLT Peak Rate (Hz) $L = 1.7 \times 10^{34}$ cm^{-2}s^{-1}
Single leptons	Single isolated μ, $p_T > 27$ GeV	20	26 (i)	15	180
	Single isolated tight e, $p_T > 27$ GeV	22 (i)	26 (i)	28	180
	Single μ, $p_T > 52$ GeV	20	50	15	61
	Single e, $p_T > 61$ GeV	22 (i)	60	28	18
	Single τ, $p_T > 170$ GeV	100	160	1.2	47
	Two μ, each $p_T > 15$ GeV	2×10	2×14	1.8	26
	Two μ, $p_T > 23, 9$ GeV	20	22, 8	15	42
			2×17	1.7	12
			7, 24	15	5
			17, 14	2.0	4
			26, 8	28	3
			35, 25	5	61
			25, 14 (i)	2.1	10
			25, 17 (i)	4	15
			24, 2×12	1.3	< 0.1
			3×6	0.2	6
			20, 2×4	15	8
			2×10, 12	1.8	0.3
			2×12, 10	1.7	0.1
			140	28	43
			50, 50	2.6	6
			35, 25	2.6	17
			2×20 (i)	1.7	14
			420	3.3	33
			460	3.3	24
			420, $m_{jet} > 40$	3.3	29
			110	5	110
			4×115	0.5	16
			5×85	5	10
			6×70	5	4
			6×55, $\lvert\eta\rvert < 2.4$	5	15
			225	3.3	15
			175, 60	3.3	12
			4×75	5	15
			2×55, 150	1.2	15
			4×55	3.2	13
			11, 6 (di-μ)	2.5	47
			2×6 (J/ψ)	1.6	48
			2×6 (B)	1.6	5
	Two μ, $p_T > 6, 6$ GeV, $7 < m(\mu,\mu) < 12$ GeV	2×6 (1, topo)	2×6 (Υ)	1.4	10
Total Rate				85	1550

HLT for LLPs (CalRatio Trigger)



- Dedicated neutral LLP trigger used in displaced jets decaying inside hadronic calorimeter
- Displaced jets have collimated showers
  - L1Tau Seed, threshold of 60 GeV (2015/16)
  - L1Topo is used to drop threshold to 30GeV by requiring L1EM veto in direction of L1TAU
  - Recovers efficiency for lower mass points
  - HLT checks for small EM/Had energy deposit

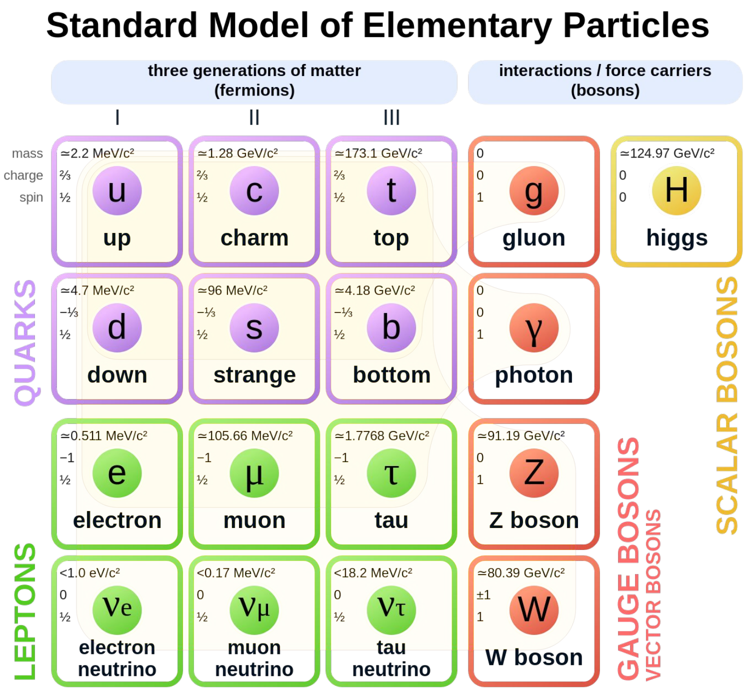


Dataset name	L1 seed (bunch crossing type)	HLT	$\int \mathcal{L}$	Usage
L1Tau dataset	L1TAU60 (paired)	CalRatio trigger	33.0 fb^{-1}	$m_\Phi \in [400, 1000]$ GeV limits
L1Topo dataset	LLP-NOMATCH (paired)	CalRatio trigger	10.8 fb^{-1}	$m_\Phi \in [125, 200]$ GeV limits
Cosmics dataset	L1TAU30 (empty)	CalRatio trigger	-	background estimation
BIB dataset	L1TAU60 (paired)	(Noiso) ∩ ¬(CalRatio)	33.0 fb^{-1}	BDT training, bkg estim.

Table 1: Summary of the data samples used for the analysis.

Tau Reconstruction & Identification

Why Tau Leptons



Privileged role in third generation

- 3Gen fermions are massive, motivates search for physics with mass dependent couplings
- In susy, stop couplings solve hierarchy problem, avoids fine tuning
- Taus are favoured w.r.t bkg rejection over top/bottom (e.g., H->tautau observed)

Tau Leptons

- Prompt tau leptons decay ~80μm (before

Decay mode	$B[\%]$
Total τ_{lep}	35.2
$\tau^- \to e^- \bar{\nu}_e \nu_\tau$	17.8
$\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$	17.4
Total τ_{had}	64.8
$\tau^- \to h^- \nu_\tau$	11.5
$\tau^- \to h^- \pi^0 \nu_\tau$	26.0
$\tau^- \to h^- \pi^0 \pi^0 \nu_\tau$	9.5
$\tau^- \to h^- h^+ h^- \nu_\tau$	9.8
$\tau^- \to h^- h^+ h^- \pi^0 \nu_\tau$	4.8
Other τ_{had}	3.2

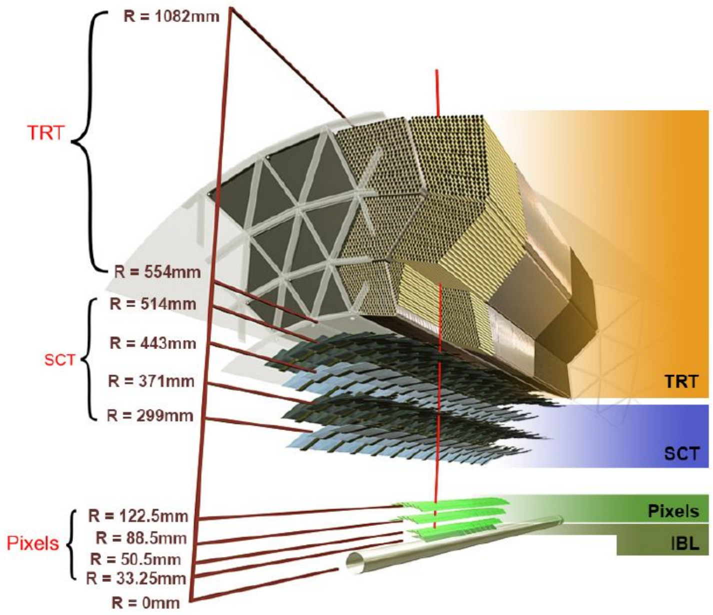
Leptonic decays not distinguishable from prompt leptons

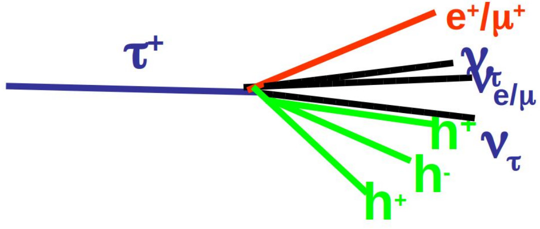
Reconstructed Taus in ATLAS are hadronic decays

Modes dep on hadron multiplicity:
1-prong: $\pi^{+/-}$ + $N\pi^0$
3-prong: $3\pi^{+/-}$+ $N\pi^0$

Associated neutrinos lost as missing energy

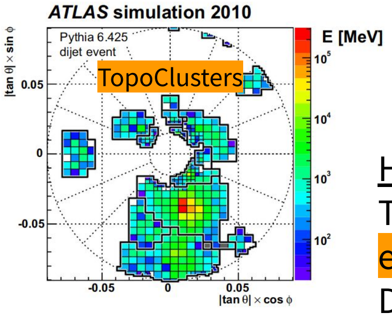
ATLAS Inner Detector





Tau Reconstruction/Identification (ATLAS)

- Tau reconstruction seed from TopoCluster Jets (robust against multiple interaction background, a.k.a., pileup)



Resulting tau candidates primarily faked by QCD jets

Handles to control BKG

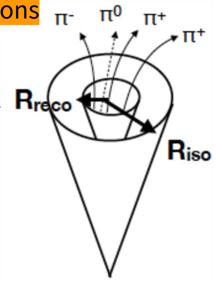
Tau Candidates have collimated energy and tracking

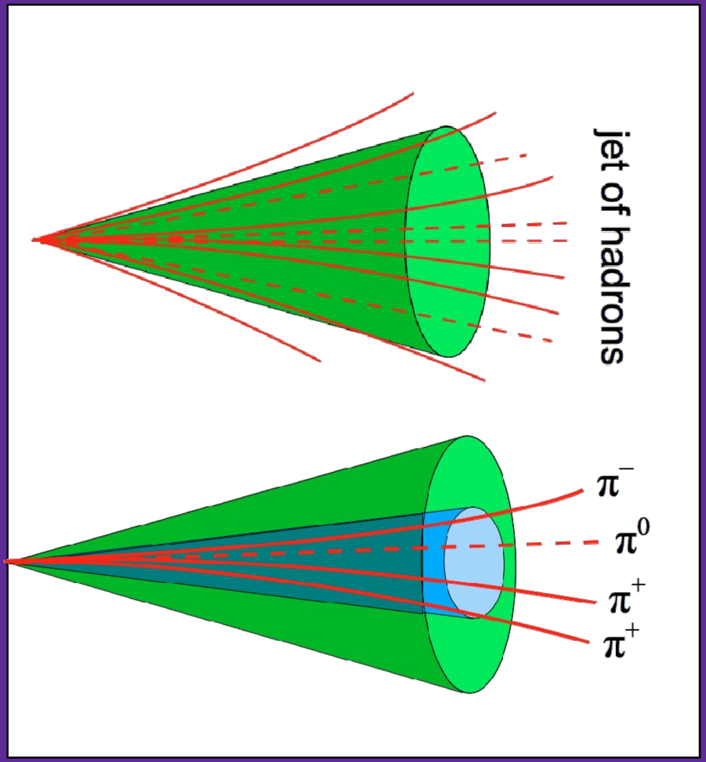
Define core/isolation regions related tracking/calo variables

Current implementation

Jet Seed → **Track Classification** → **Tau ID BDT/RNN**

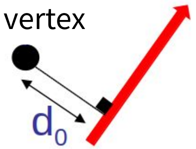
Core/Isolation regions



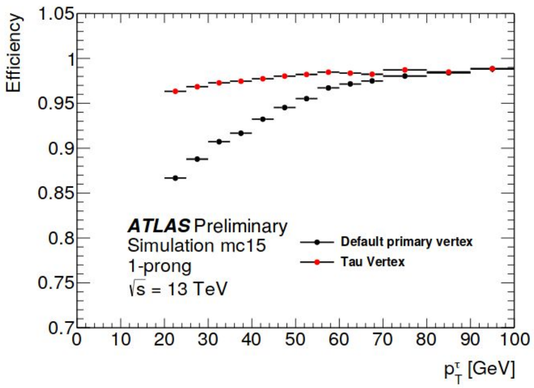


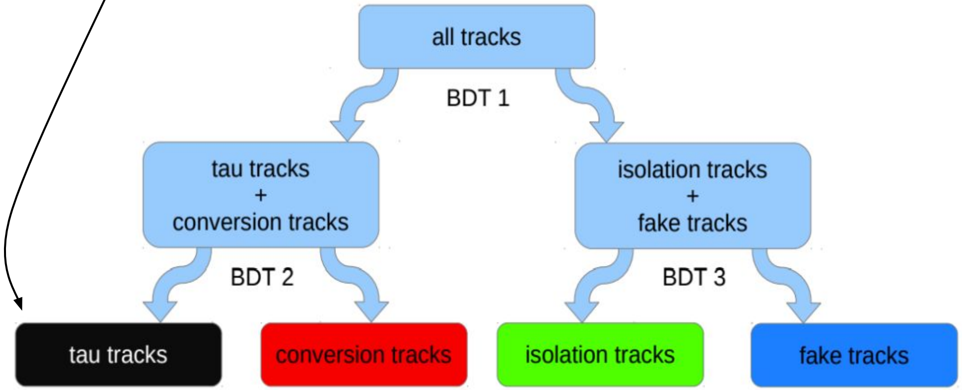
Tau Track Classification

- Tau Vertex highest $\Sigma p_T^{track\ (\Delta R<0.2,\ pt > 0.5\ GeV)}$ vertex)
  Tau Tracks are within ΔR<0.4 of vertex
- BDT used to classify tracks as
  - pT, d0, z0, nPix, nSCT
  - Classify into isolation and TauTracks -> used to define 1/3 -prong



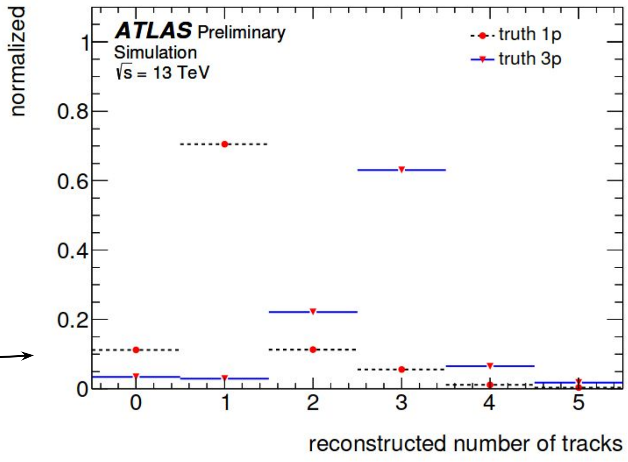
TauVertex vs PrimaryVertex Efficiency





ATL-PHYS-PUB-2015-045

track classification performance



<u>Track classifier leading cause of tau inefficiency:</u>
misclassified tracks, incorrect vertex matching,
very high-pT effects (merged tracks and missing pixel hits)

Tau Track Classification

- Tau Vertex highest $\Sigma p_T^{track\ (\Delta R<0.2,\ pt > 0.5\ GeV)}$ vertex)
  Tau Tracks are within ΔR<0.4 of vertex
- BDT used to classify tracks as
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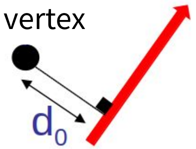
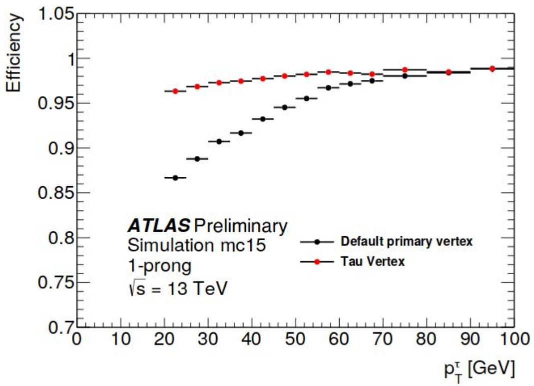
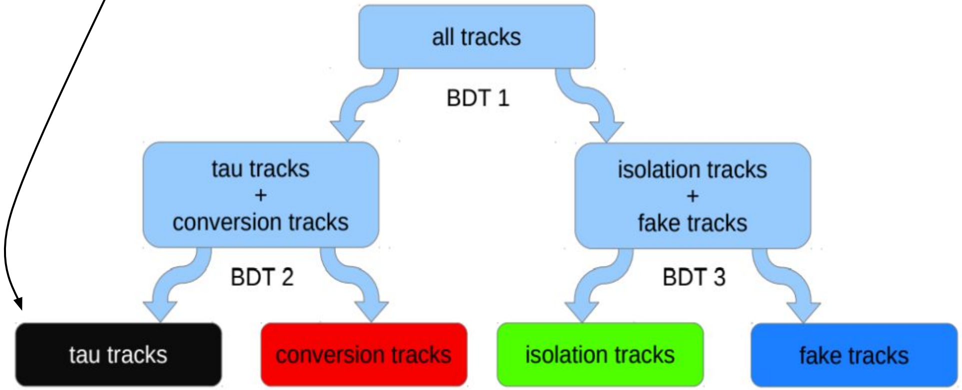
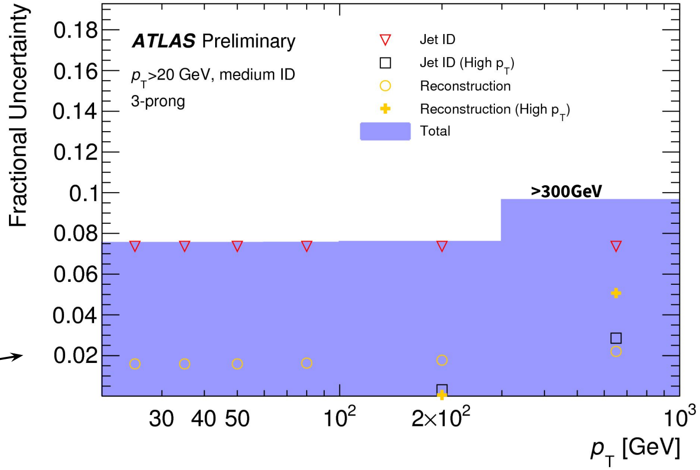


TauVertex vs PrimaryVertex Efficiency





Reconstruction uncertainties dominate at high pT



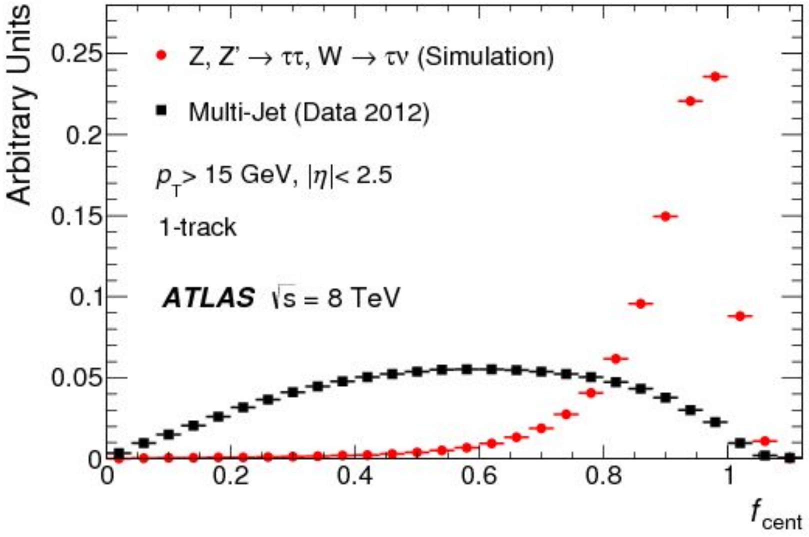
Track classifier leading cause of tau inefficiency:
misclassified tracks, incorrect vertex matching, very high-pT effects (merged tracks and missing pixel hits)

Tau Identification (BDT)

- BDT trained with calorimeter and tracking input variables separately for 1- and 3-track taus (track momenta/position, and lifetime information)
- Trained on Z/gamma samples (for prompt taus)

E.g., Central Fraction

energy in ΔR<0.1 cone
energy in ΔR<0.2 cone



Variable	Offline 1-track	Offline 3-track
f_{cent}	•	•
f_{track}	•	•
R_{track}	•	•
$S_{\mathrm{lead\ track}}$	•	
$N_{\mathrm{track}}^{\mathrm{iso}}$	•	
ΔR_{Max}		•
$S_{\mathrm{T}}^{\mathrm{flight}}$		•
m_{track}		•
$m_{\pi^0+\mathrm{track}}$	•	•
N_{π^0}	•	•
$p_{\mathrm{T}}^{\pi^0+\mathrm{track}}/p_{\mathrm{T}}$	•	•

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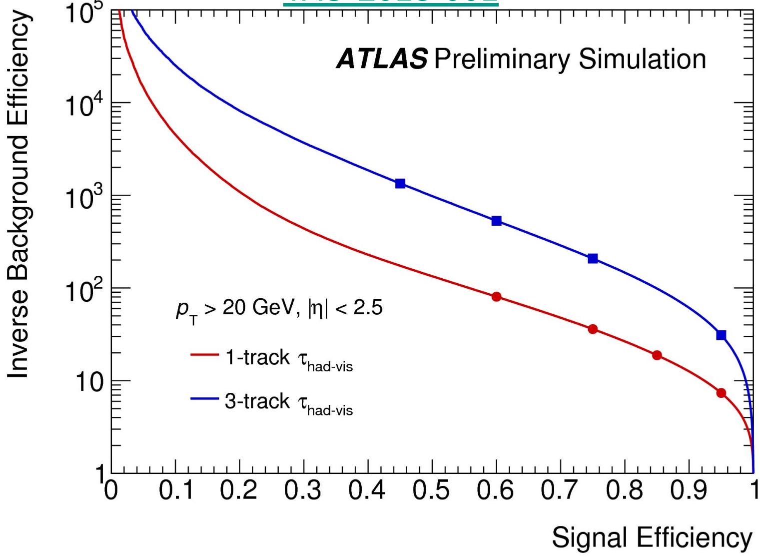
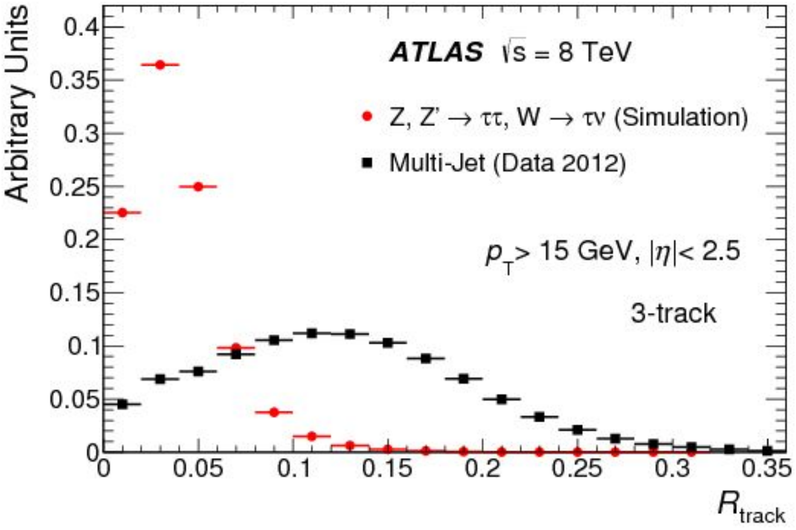


Tau Identification (BDT)

- BDT trained with calorimeter and tracking input variables separately for 1- and 3-track taus (track momenta/position, and lifetime information)

Variable	Offline	
	1-track	3-track
f_{cent}	•	•
f_{track}	•	•
R_{track}	•	•
$S_{\mathrm{lead\ track}}$	•	
$N_{\mathrm{track}}^{\mathrm{iso}}$	•	
ΔR_{Max}		•
$S_{\mathrm{T}}^{\mathrm{flight}}$		•
m_{track}		•
$m_{\pi^0+\mathrm{track}}$	•	•
N_{π^0}	•	•
$p_{\mathrm{T}}^{\pi^0+\mathrm{track}}/p_{\mathrm{T}}$	•	•

E.g., R_{track}
pT-weighted sum of track in core regions
to radius to jet seed



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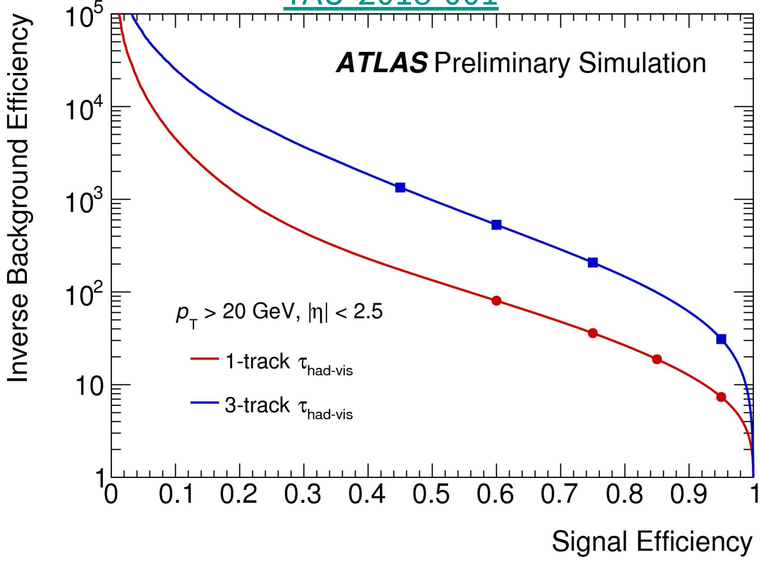
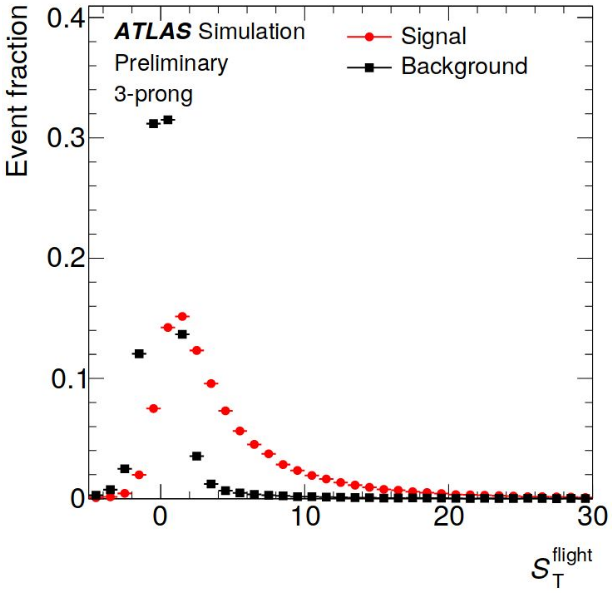


Tau Identification (BDT)

- BDT trained with calorimeter and tracking input variables separately for 1- and 3-track taus (track momenta/position, and lifetime information)

Variable	Offline 1-track	Offline 3-track
f_{cent}	•	•
f_{track}	•	•
R_{track}	•	•
$S_{\text{lead track}}$	•	
$N_{\text{track}}^{\text{iso}}$	•	
ΔR_{Max}		•
$S_{\text{T}}^{\text{flight}}$		•
m_{track}		•
$m_{\pi^0+\text{track}}$	•	•
N_{π^0}	•	•
$p_{\text{T}}^{\pi^0+\text{track}}/p_{\text{T}}$	•	•

E.g., S_T^{flight}
Distance of secondary vertex wrt TV divided by uncertainty (multi-prong)



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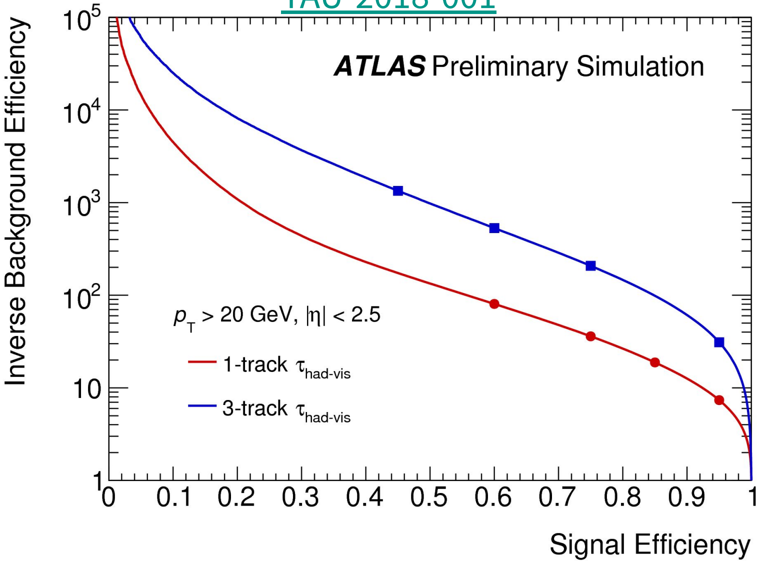
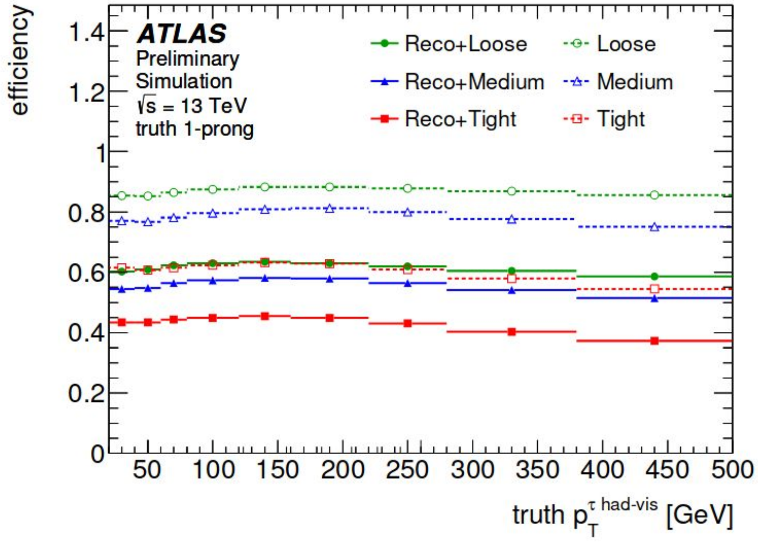
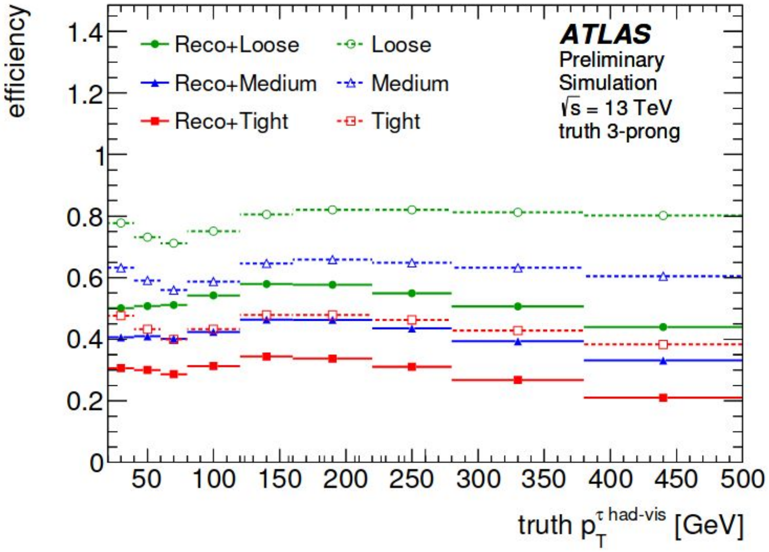


Tau Identification (BDT)

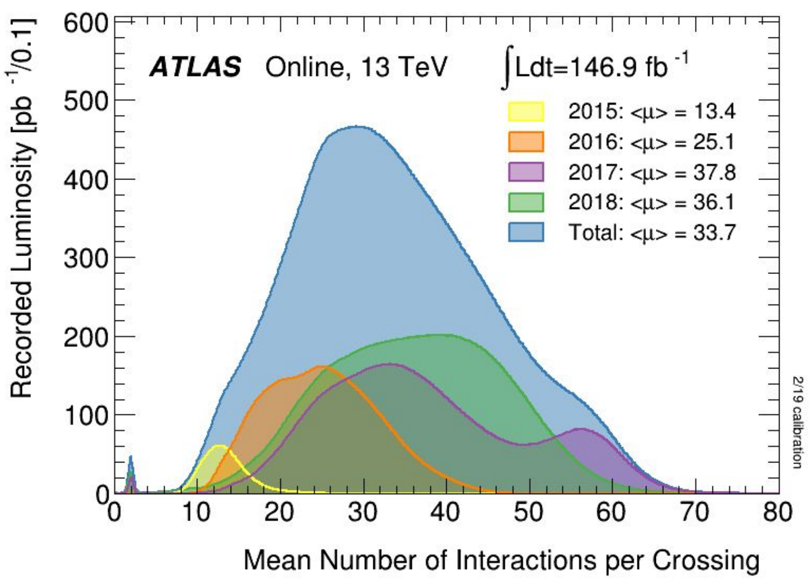
- Tau identification provided at analysis level for particular working points, i.e., sig/bkg efficiency
- Total efficiency of tau candidates = identification reconstruction efficiency
  - Approx flat 60% for 1-prong for loose identification, 45-60% for 3-prong

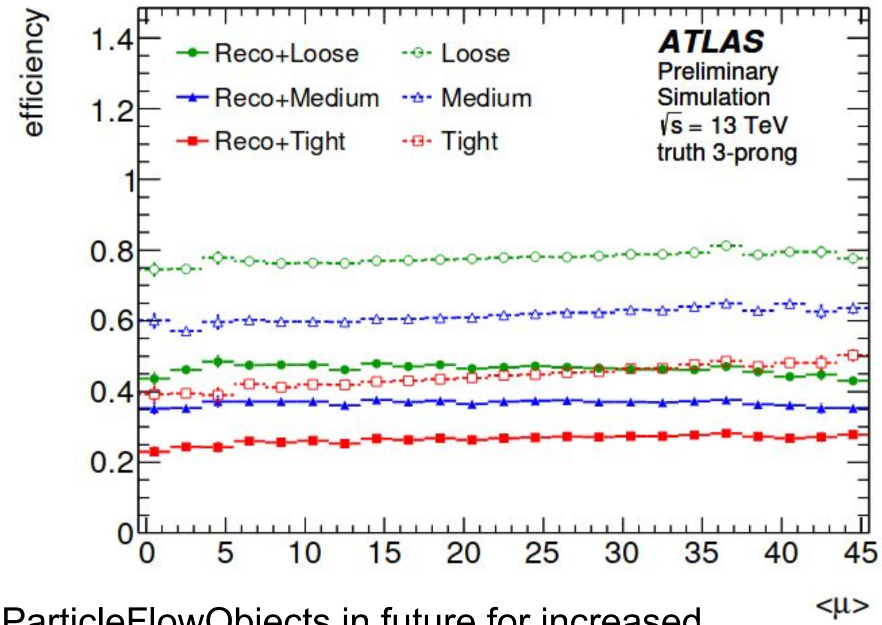




Tau Identification (BDT)

- Efficiencies are robust against additional interactions per-crossing (pileup)
  - Topoclusters are pileup robust*
  - BDT variables include varage pileup energy subtractions

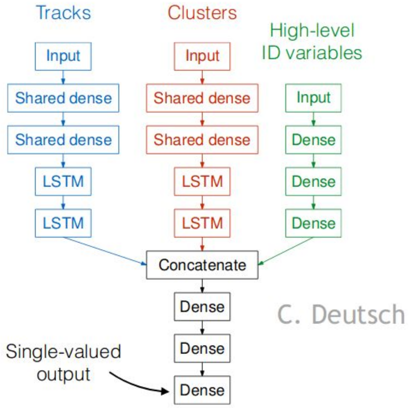


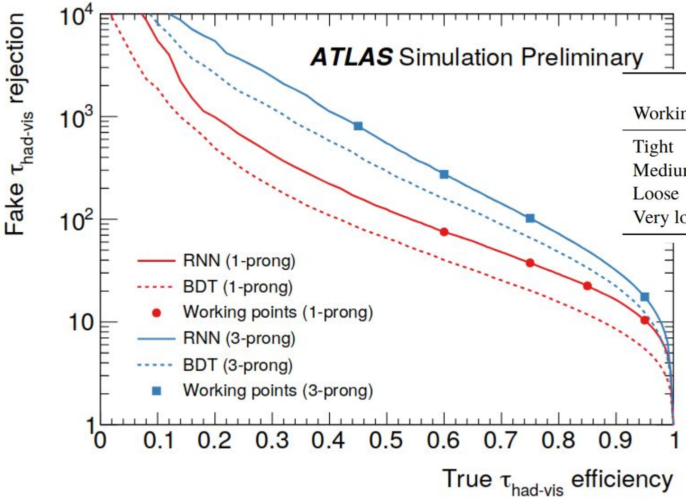


* ATLAS looking move away from Topocluster Jets to ParticleFlowObjects in future for increased performance at high luminosities

Tau Identification (RNN)

- RNN
  - Runs after the track selection algorithm
  - Inputs: tau candidates with 1 or 3 tracks
  - Trained separately for 1- and 3-prong taus
- Rejection improvement of ~35% over BDT version
- Variables used:
  - Tracks (up to 10 tracks, pT ordered) : pT, d0, z0 sinθ, Δφ, Δη, track quality
  - Clusters (up to 6, ET-ordered): ET, Δφ, Δη, cluster moments
  - High-level ID variables: invariant masses, secondary vertex information, etc.





Working point	Signal efficiency 1-prong	Signal efficiency 3-prong	Background rejection BDT 1-prong	Background rejection BDT 3-prong	Background rejection RNN 1-prong	Background rejection RNN 3-prong
Tight	60%	45%	40	400	70	700
Medium	75%	60%	20	150	35	240
Loose	85%	75%	12	61	21	90
Very loose	95%	95%	5.3	11.2	9.9	16

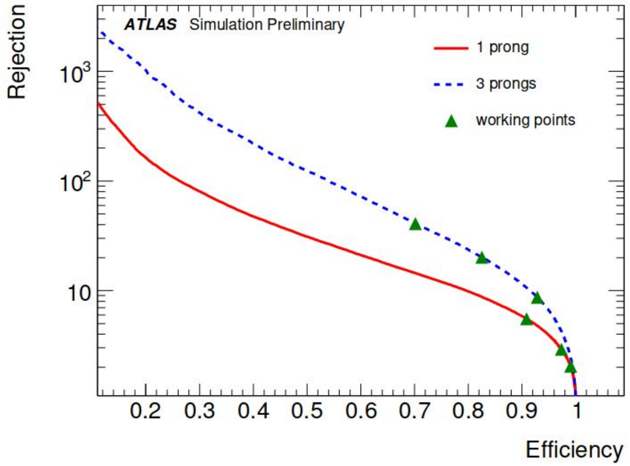
	Observable	1-prong	3-prong
Track inputs	$p_T^{seed\ jet}$	•	•
	p_T^{track}	•	•
	$\Delta\eta^{track}$	•	•
	$\Delta\phi^{track}$	•	•
	$\lvert d_0^{track}\rvert$	•	•
	$\lvert z_0^{track} \sin\theta\rvert$	•	•
	$N_{IBL\ hits}$	•	•
	$N_{Pixel\ hits}$	•	•
	$N_{SCT\ hits}$	•	•
Cluster inputs	$p_T^{jet\ seed}$	•	•
	$E_T^{cluster}$	•	•
	$\Delta\eta^{cluster}$	•	•
	$\Delta\phi^{cluster}$	•	•
	$\lambda_{cluster}$	•	•
	$\langle\lambda^2_{cluster}\rangle$	•	•
	$\langle r^2_{cluster}\rangle$	•	•
High-level inputs	$p_T^{uncalibrated}$	•	•
	f_{cent}	•	•
	$f^{-1}_{leadtrack}$	•	•
	ΔR_{max}	•	•
	$\lvert S_{leadtrack}\rvert$	•	
	S_T^{flight}		•
	f_{iso}^{track}	•	•
	f_{track}^{EM}	•	•
	$p_T^{EM+track}/p_T$	•	•
	$m^{EM+track}$	•	•
	m^{track}		•

Tau Identification (Online) Details

1. Calo Only Preselection
- Candidates reconstructed purely from calo info (EM isolation requirements < 60GeV)
- Topo-clusters calibrated (LC) and summed vectorially (jet seed)
- LC around (ΔR<0.2) barycenter defines tau energy
- TES calibration applied, similar to offline

2. Track Preselection
- 2 stage FTF selection
- Tau Core and Isolation Tracks are identified with MVA approach (like offline)

3. Offline-like Preselection
- Precision tracking on selected tracks to improve accuracy.
- Use tracks + calo info
- Calo variables calculated for RNN
- Cut on RNN/BDT score to finalise trigger selection
- 3 ID WSs with dependant on prong
- Track multiplicity requirements loosened at ~200 GeV, selection WP loosened at ~400 GeV (jet-like trigger)



BDT variables ATLAS-CONF-2017-061

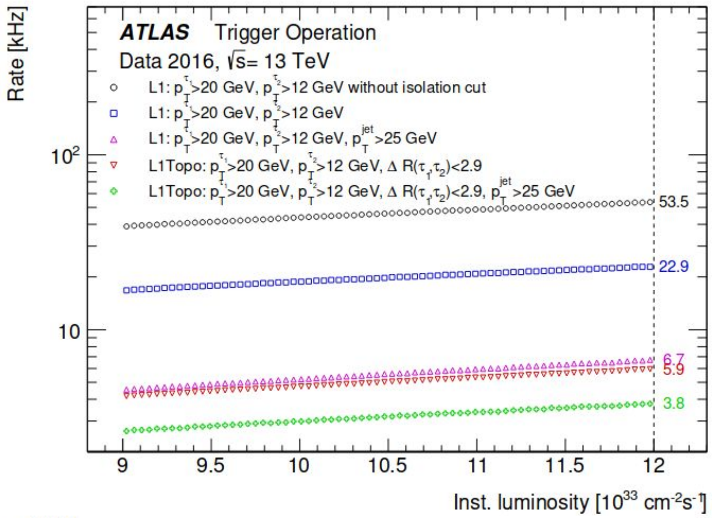
Variable	Description	1-prong	multi-prong
f_{cent}	Central energy fraction	•	•
$f^{-1}_{\mathrm{leadtrack}}$	Leading track momentum fraction	•	•
R_{track}	Track radius	•	•
$\lvert S_{\mathrm{leadtrack}} \rvert$	Leading track impact parameter significance	•	
$f^{\mathrm{track}}_{\mathrm{iso}}$	Fraction of p_{T} from tracks in the isolation region	•	
ΔR_{Max}	Maximum ΔR		•
$S^{\mathrm{flight}}_{\mathrm{T}}$	Transverse flight path significance		•
m_{track}	Track mass		•
$f^{\mathrm{track-HAD}}_{\mathrm{EM}}$	Fraction of EM energy from charged pions	•	•
$f^{\mathrm{EM}}_{\mathrm{track}}$	Ratio of EM energy to track momentum	•	•
$m_{\mathrm{EM+track}}$	Track-plus-EM-system mass	•	•
$p^{\mathrm{EM+track}}_{\mathrm{T}}/p_{\mathrm{T}}$	Ratio of track-plus-EM-system to p_{T}	•	•

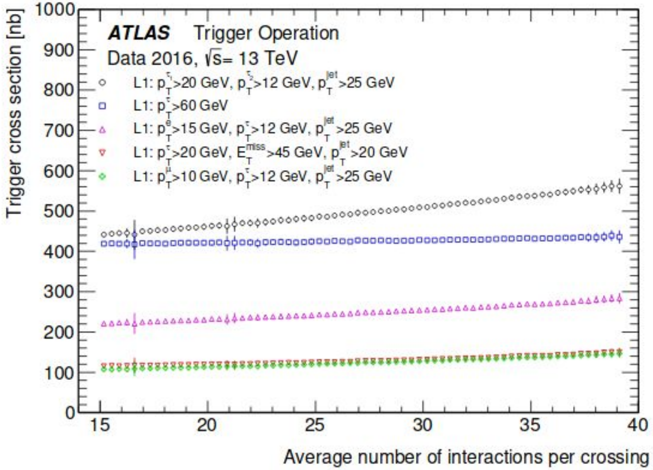
Online Taus, the cost

ATLAS-CONF-2017-061

- Mangable rates for tau triggers difficult due to high rates at L1
- For Single Tau trigger requires high threshold
- Tau+X triggers can offer reduced tau pT, at the cost of additional associated jets
- Di-Tau Topological selection available without associated jets using angular separation requirement

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
τ+μ	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
τ+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
	$p_T^\tau > 40, 30$ GeV, $\Delta R(\tau,\tau) < 2.6$, $p_T^{jet} > 80$ GeV	20i,12i,2.9,25	35,25,-,-	3.8	24





Online Taus, the cost

- Most of CPU time on tracking stages
- Potential room for improvement, FTF will need retune in Run-3 (can it deal with pileup)

- Displaced Taus?
  - Tau seed from track in first stage
  - However this stage is wide scan (|Δ z|<225 mm)
  - Spurious sources of tracks will tend to kickstart TauID, but a 0-prong mode could be used to recver efficiency?
  - Can we optimize procedure for displaced tau?

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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

Tau Particle Flow and Calibration

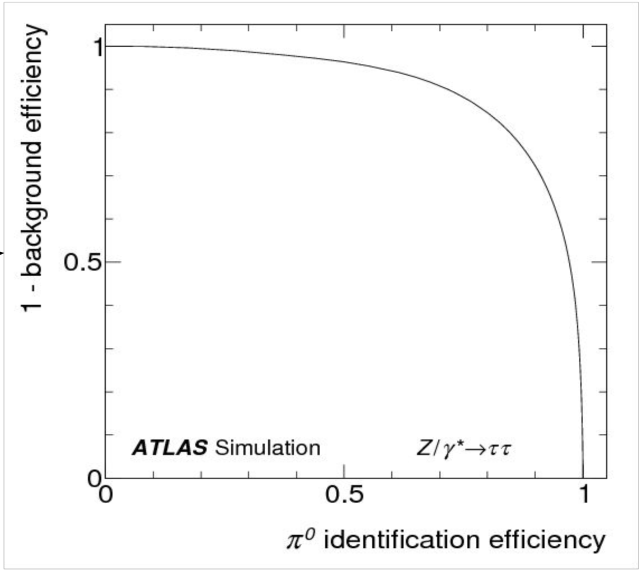
Tau Particle Flow (TPF)

- Identify the detector signature of individual tau decay products (charged and neutral pions) in order to:
  - Identify the decay mode (1p0n, 1p1n, 1pXn, 3p0n, 3pXn)
  - Better reconstruct the momentum (use tracking information!)

TPF How To

1. Track/Cluster matching to identify $\pi^{+/-}$ and energy rescaling
2. MVA π^0 identification (reject bkg π^0) and 1p mode separation
3. BDT re-cover the most likely migrations

π^0 MVA using cluster moments



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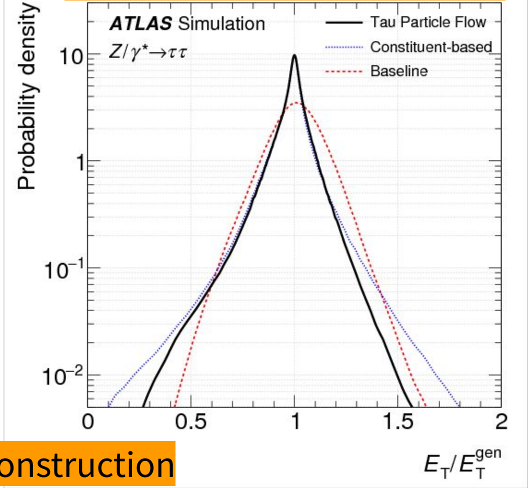
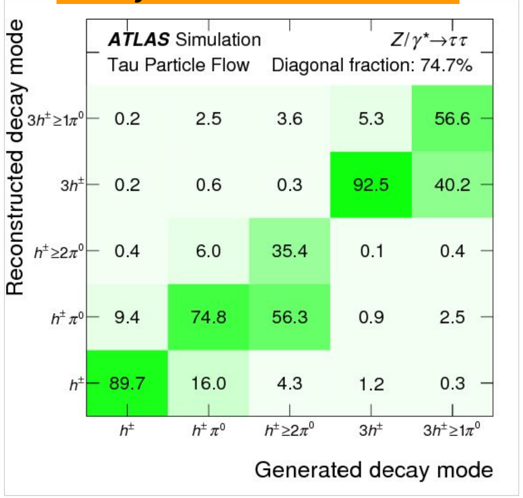
Tau Particle Flow

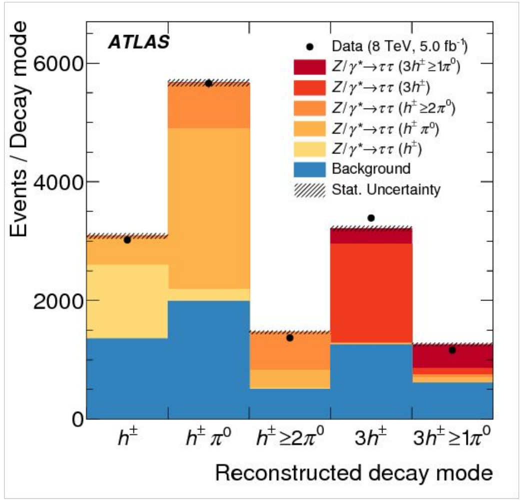
- Resulting decay mode classification
  - Improves energy resolution and propagated into energy scale measurements (discussed later)
  - Vital for precision measurements and useful for polarisation information

Improved Energy Resolution



Decay mode classification





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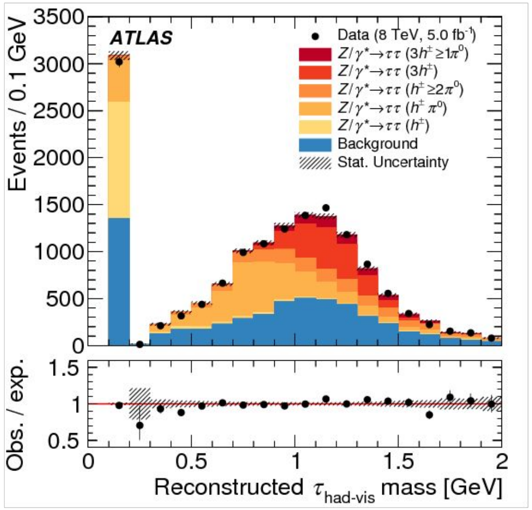
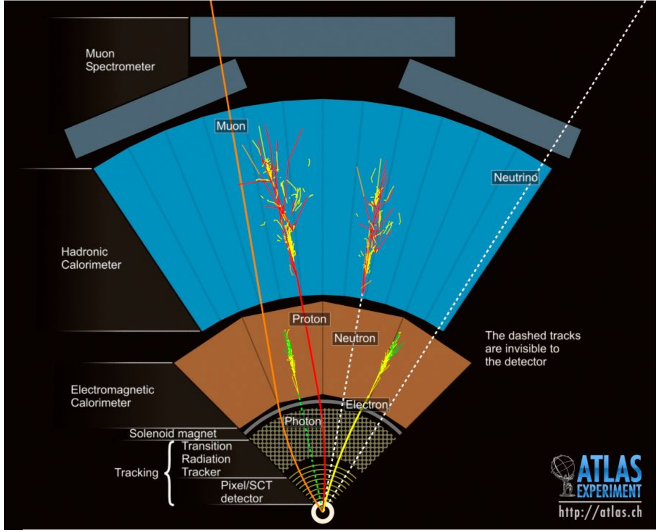
Mass reconstruction



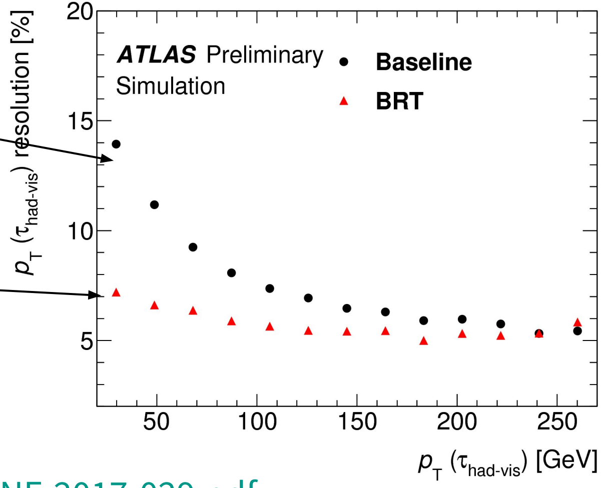
Tau Energy Calibration

- TopoCluster energy calibrated with Local Calibration (LC)
- ATLAS Calorimeter uses sampling layers,
  - Energy loss assumptions different for EM/Had objects



Two Approaches

1. Baseline Calo-Based
   Tau Energy is calibrated starting from LC Jet
   a. Detector response/resolution corrected to visible tau energy in simulation
   b. Taking into account pileup dependance (<mu>, eta, prong) $\left(E_{\mathrm{LC}} - E_{\mathrm{pileup}}\right) / E^{\mathrm{vis}}_{\mathrm{true}}$



2. Boosted Regression Tree
   a. Use TauParticleFlow flow
   b. Reconstruct individual neutral and charged hadrons
   c. Gives improved resolution

Interpolation approach applied for analysis/uncertainties

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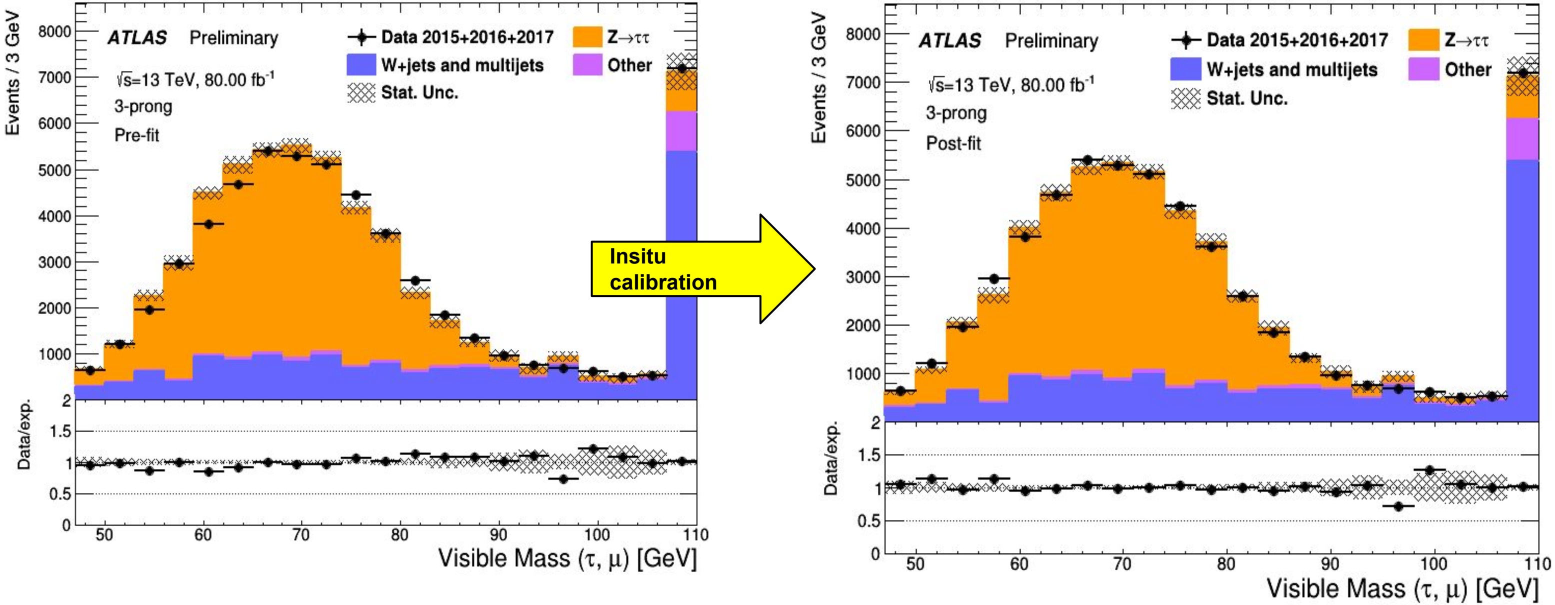
Tau Energy Calibration (In-situ correction)

- Additional correction from data-driven difference in Z mass shape
- Evaluated in Z->μτ. Applied for taus < 70 GeV.



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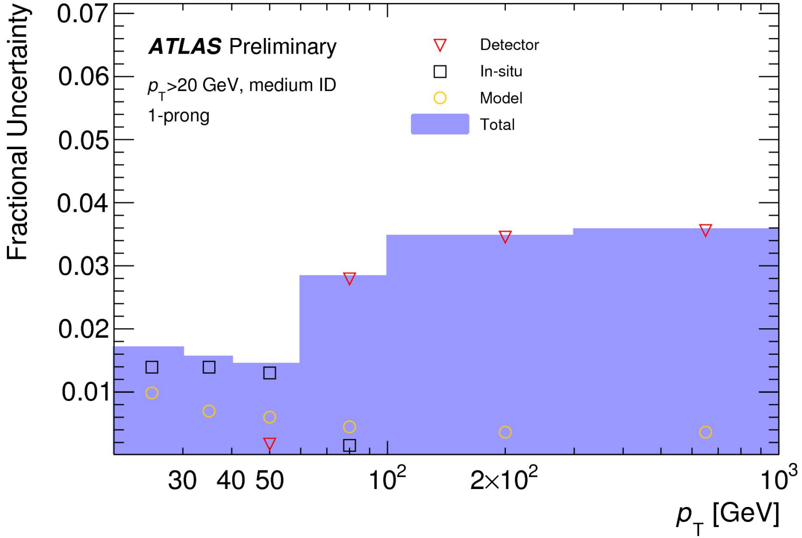
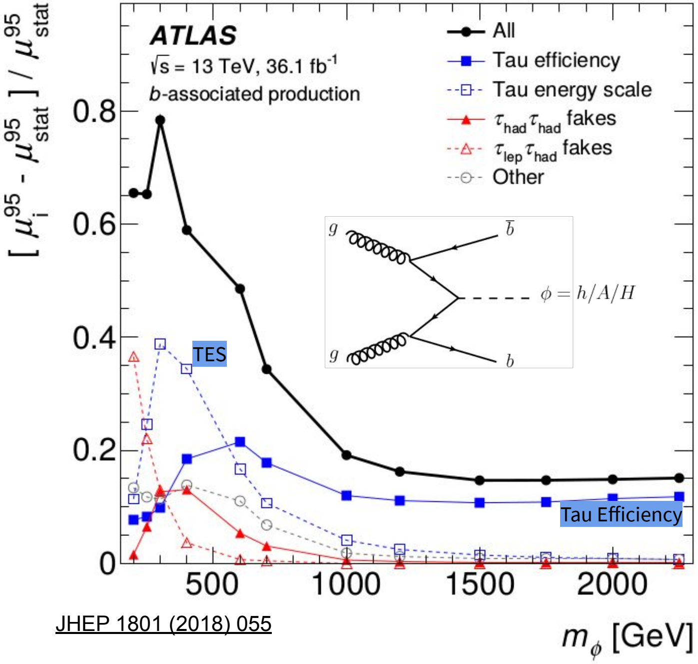
Tau Energy Uncertainties

- Detector: Material, Calorimeter Noise
- Model: Generator, Showering, Hadronisation
- In-situ: Mass shape correction in Z->τμ (taus <70GeV)



Leading uncertainties in systematic dominated tau searches, e.g., A/H->ττ (BSM)



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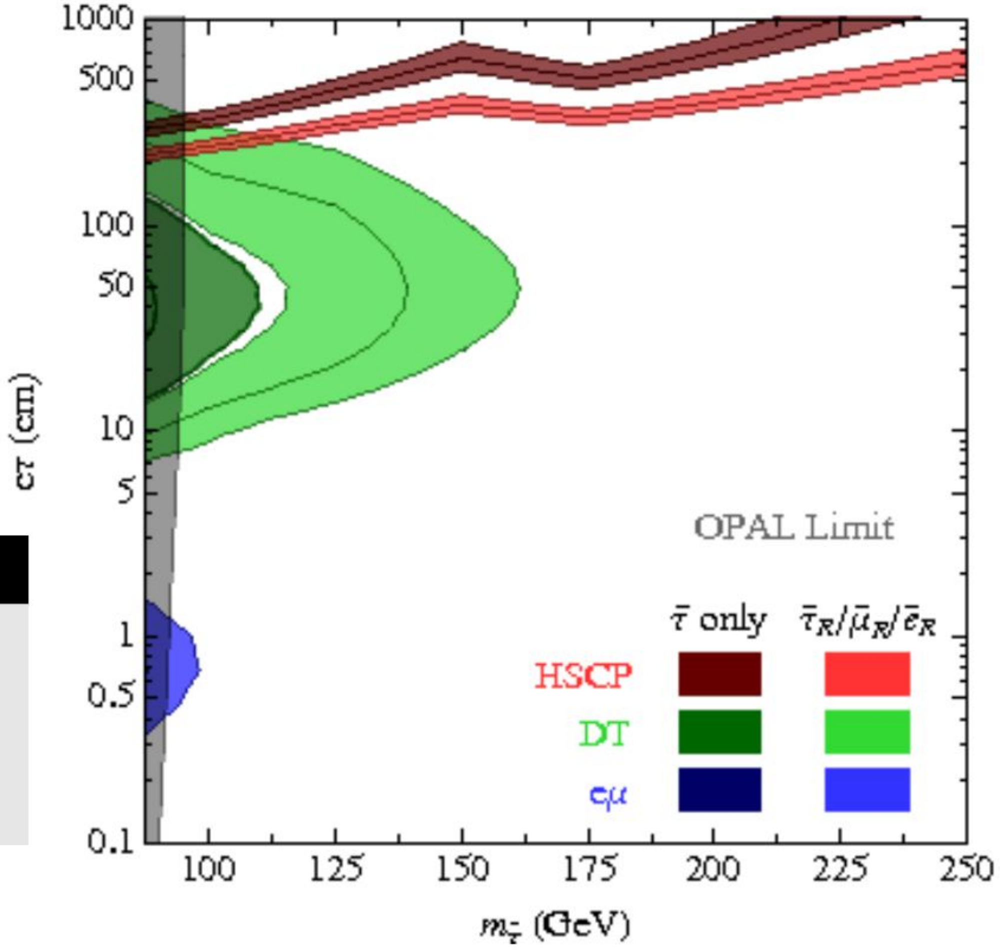
LLP Searches with Taus (What to consider)

Taus from LLPs

- LLPs decaying to 3rd gen. fermions [well-motivated](#) but poorly constrained
- e.g, displaced e/μ searches for leptonic τ decays (low-BR).

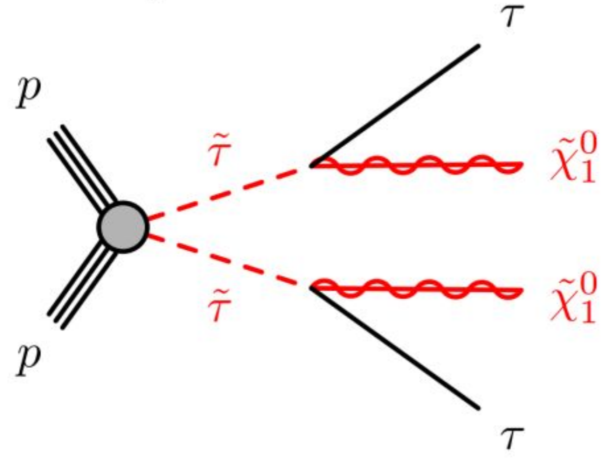
Analysis Goals

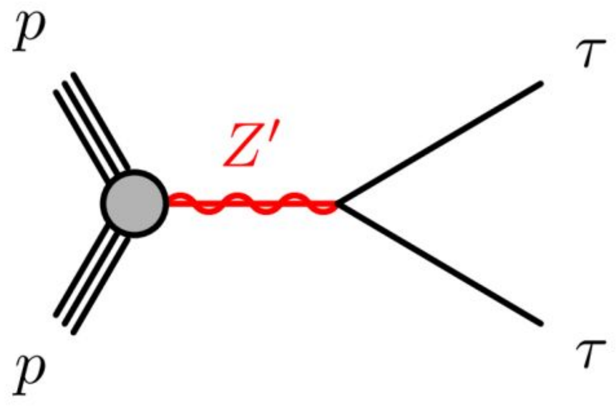
- Target hadronic taus (model independent)
  - semi-leptonic or
  - fully hadronic **(triggers. . .)**
  - associated objects (`WH,H->aa` , HNL, . . .)



Taus from LLPs

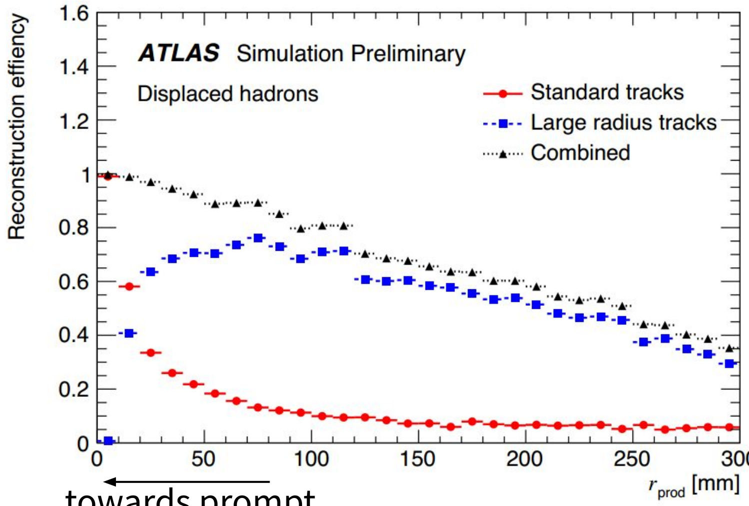
- Targeting hadronic tau has several challenges which are being addressed internally
- Tau-ID
  - MVA tracking particular bottle-neck feeding ID,
    - Classification trained for prompt
    - Tracks not suitable for large decay radius
  - RNN/BDT identification trained for prompt taus
- Calibration? TPF?
- Trigger
  - Tracking at HLT not optimised for displaced taus
  - Tau triggers suffer from large background
    - Single tau triggers have hefty kinematic thresholds (up to 200 GeV)
    - Di-Tau triggers come with topological requirements
  - Including associated/prompt triggers? Next slide
- Both need novel approaches





Displaced Tau ID?

- Bottleneck for displaced tau in ID is dependent on track classification from nominal tracks
- One approach might be to use Large Radius Tracking, under investigation



towards prompt

towards colorimeter approach

	Standard	Large radius
Maximum d_0 (mm)	10	300
Maximum z_0 (mm)	250	1500
Maximum $\|\eta\|$	2.7	5
Maximum shared silicon modules	1	2
Minimum unshared silicon hits	6	5
Minimum silicon hits	7	7
Seed extension	Combinatorial	Sequential

Larger d0 track collection could be used to inform track classifier and RNN ID. Possibly a decay radius dependant performance.

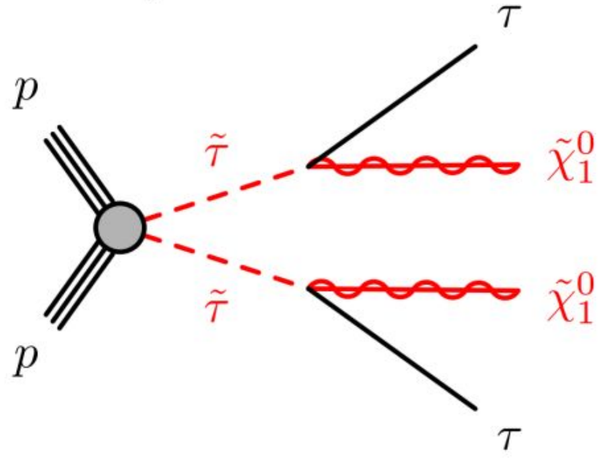
Alternatively could consider a calorimeter only approach

Tau Trigger

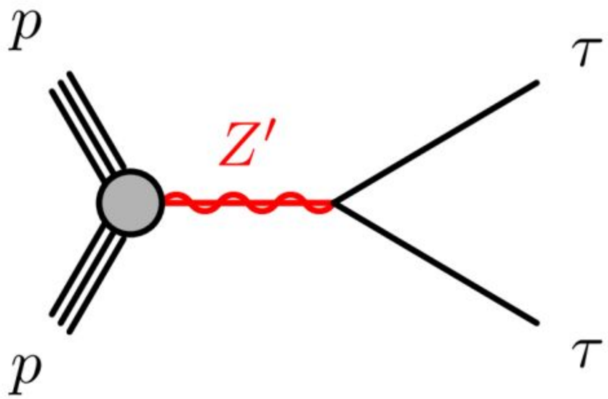
- Not so dependent of tracking at trigger level due to limited resources
- 0-prong mode exists and is optimised in RNN to recover some efficiency for prompt
- Possibility to tune triggers to be robust for displaced taus in Run-III

Alternatives to Displaced Tau Triggers

- Could consider case where 1stau is prompt, other stau long-lived
- Trigger on prompt e/mu/tau, probe displaced object
- Triggering on prompt lepton interpretable for WH->aa->4tau or HNL



- For pair produced tau from LLP, e.g., use displaced muon trigger for semi-leptonic mode



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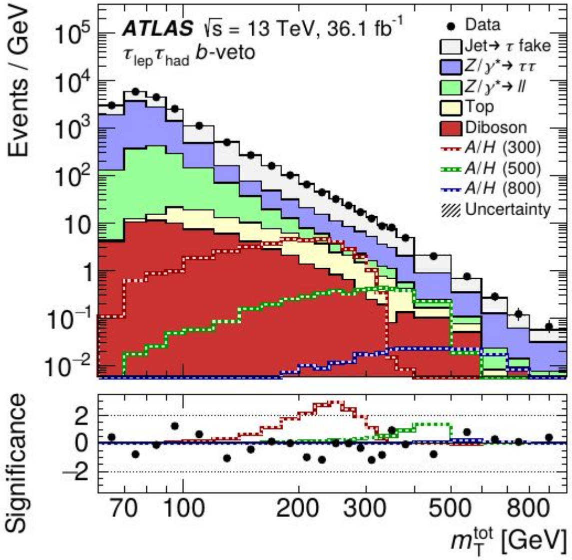
Taus from LLPs

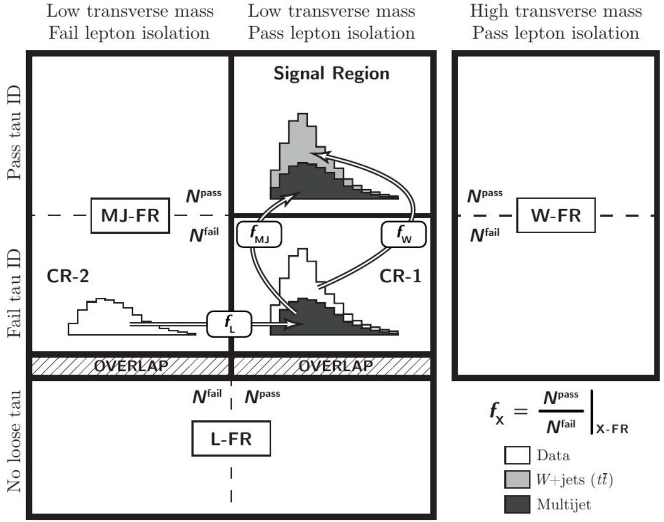
- Assuming novel Tau-ID and Trigger, what techniques might we need to use? In a close to prompt regime, might not be Zero BKG

- **Background sources?**
  - **Different rates of tau-fakes from q/g-jets**



  - **QCD and W+jets backgrounds estimated with data driven methods**

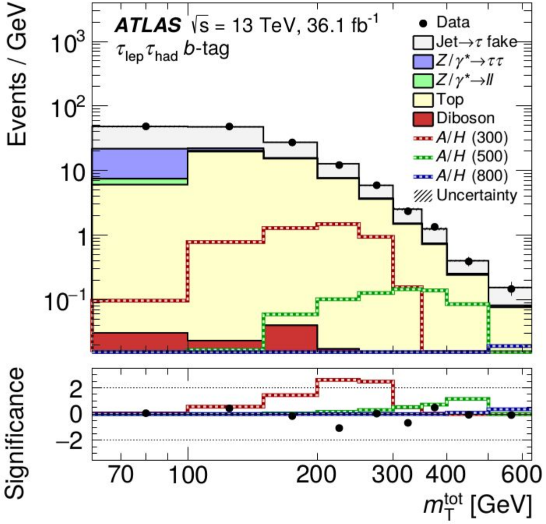
Fake-factor method in A/H->ττ
Invert tau-quality criteria to build templates in orthogonal regions



Or will searches be dominated by Cosmics or Beam-Induced BKG?

What about interpretability?

A/H->ττ set limits using m_T variable, was able to reinterpret result in Z'



But probably single bin fit stats, so is this relevant?

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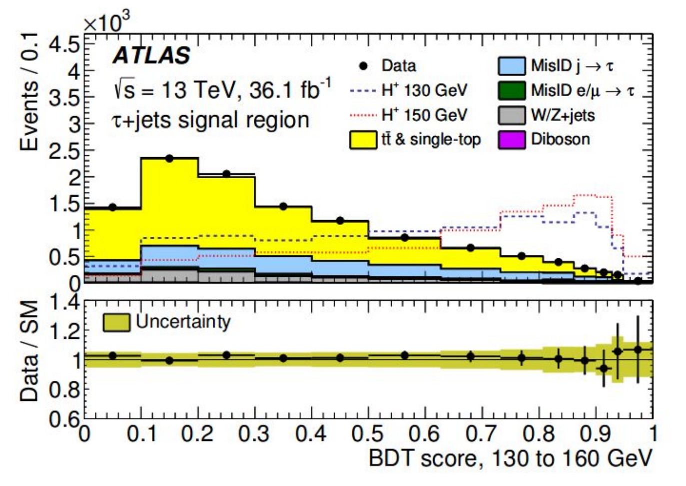
Charged Higgs uses BDT as final discriminant, else low mass analysis insensitive



Charged Higgs

Summary

Summary

- Tau Reconstruction/Identification/Calibration/Triggering capabilities in Run 2 are cornerstone to prompt tau analysis in Run-II.
- Currently working on how to adapt techniques useful for tau anlysis to LLPs
    - LLP->taus underdeveloped area, with a lot of work that can be done!
- Several triggers are specifically designed for LLP signatures
    - Fully hadronic trigger is challenging due to large backgrounds and non-optimal training for LLPs
    - Need to assess if there will be something to gain from additional granularity and Topo from L1 at Run-3
    - Analysis will likely use a tapestry of triggers: MET, lepton (prompt/displaced), hadronic tau, jets
- Tau identification for LLPs suffers from prompt RNN/BDT training
    - Possible gains from large radius tracking and dedicated long-lived training samples
- Many other considerations: LLP tau calibration, models/triggers to use, object multiplicities, final discriminants, etc.

Backup

- Tau tracks (TT): tracks from the direct tau decay
- Conversion tracks (CT): tracks from conversions, hadronic interactions, “long” living particles (barcode > 200k)
  - Important due to neutral pions
- Isolation tracks (IT): tracks with barcode < 10k which are no TT → mainly tracks from underlying event
- Fake tracks (FT): not truth matched tracks, tracks with low matching probability (<0.5), tracks with barcode between 10k and 200k