ttH multilepton: background estimation

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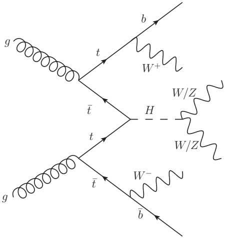
Introduction

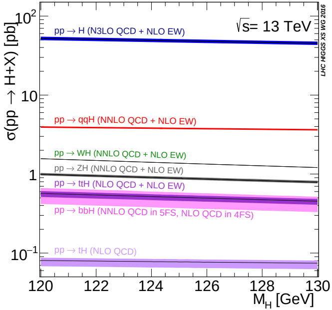
$t\bar{t}H$ associated production allows tree - level measurement of the Higgs Yukawa coupling to top-quarks.

Due to the small cross section, it has been eluding observation.

Observation is becoming possible with the increasing datasets collected by ATLAS and CMS.

Already CMS has reported observation of the $t\bar{t}H$ production with an observed (expected) significance of 5.2σ (4.2σ) arXiv:1804.02610.





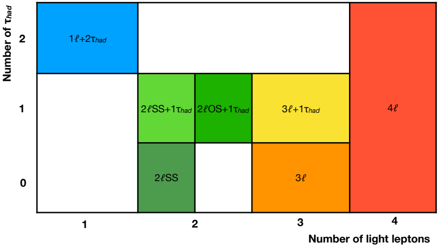
CMS: arXiv:1803.05485
ATLAS: Phys.Rev.D97(2018)no.7

Introduction

$t\bar{t}H \rightarrow$ multilepton decay is one of the most sensitive channels in this search.

7 (6) analysis categories are defined by ATLAS (CMS), according to:

- number of light leptons (e,μ)
- number of hadronically decaying taus (τ_{had}).



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Background contributions

Prompt lepton backgrounds obtained from MC simulation, validated with the data:

- $t\bar{t}V$,
- VV+jets,
- Rare: $t\bar{t}WW$, tH, tZ, WtZ, VVV, $tt\bar{t}\bar{t}$.

Non-prompt-lepton& electron charge-flip background

- significantly reduced by tight object $(e, \mu, \tau_{\mathrm{had}})$ identification criteria (incl. BDT);
- main source of background in the pre-MVA region.

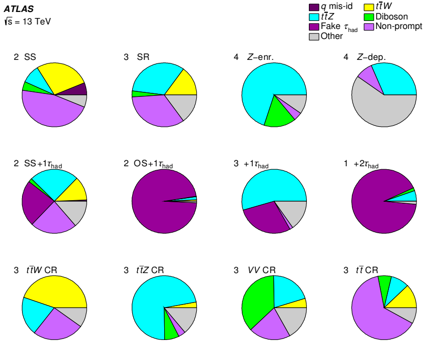

Figure: *Background contribution in the defined analysis categories.*

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Background rejection BDTs

Non-prompt-lepton BDT

Variable	Description
N_{track} in track jet	Number of tracks collected by the track jet
IP2 $\log(P_b/P_{\text{light}})$	Log-likelihood ratio between the b and light jet hypotheses with the IP2D algorithm
IP3 $\log(P_b/P_{\text{light}})$	Log-likelihood ratio between the b and light jet hypotheses with the IP3D algorithm
N_{TrkAtVtx} SV + JF	Number of tracks used in the secondary vertex found by the SV1 algorithm in addition to the number of tracks from secondary vertices found by the JetFitter algorithm with at least two tracks
$p_T^{\text{lepton}}/p_T^{\text{track jet}}$	The ratio of the lepton p_T and the track jet p_T
ΔR(lepton, track jet)	ΔR between the lepton and the track jet axis
p_TVarCone30$/p_T$	Lepton track isolation, with track collecting radius of $\Delta R < 0.3$
E_TTopoCone30$/p_T$	Lepton calorimeter isolation, with topological cluster collecting radius of $\Delta R < 0.3$

- 70%/60% efficiency for $\mu(e)$ at $p_{\mathrm{T}} = 10$ GeV*
- 98%(96%) for $p_{\mathrm{T}} > 45$ GeV.
- rejection ~20 of leptons from b hadrons.

(*lepton candidate $p_{\mathrm{T}} > 20$ GeV).

Electron charge mis-ID BDT

Variable	Description
p_{T}	Transverse momentum
η	Pseudo-rapidity
charge$\times d_0$	Electric charge times the transverse impact parameter
E/p	Ratio of the cluster energy to the track momentum
R_ϕ	Ratio of the energy in 3×3 cells over the energy in 3×7 cells centred at the electron cluster position
$\Delta\phi_1$	$\Delta\phi$ between the cluster position in the strip layer and the extrapolated track
$\Delta\phi_{rescaled}$	$\Delta\phi$ between the cluster position in the middle layer and the extrapolated track, where the track momentum is rescaled to the cluster energy before extrapolating the track to the middle layer
$\frac{q/p}{\sigma_{q/p}}$	Significance of the curvature of the track defined as the ratio of the reconstructed charge to the track momentum

- 95% efficiency for right charge electrons.
- rejection ~17 of wrong charge electrons.

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Non-prompt-lepton background

Events with non-prompt-leptons (fake):

- semi-leptonic B/C-hadron decays;
- mis-identification of hadronic jets as electrons;
- γ conversions,

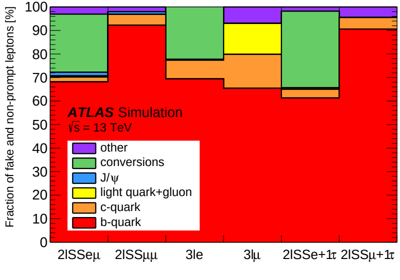

Figure: *Non-prompt light-lepton composition*

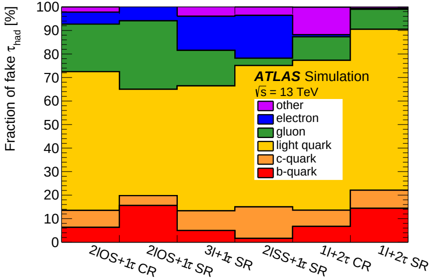

Figure: *Non-prompt* τ_{had} *composition*

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Fake Factor Method

The **ratio** θ of fake-leptons passing/failing the tight ID criteria is measured in a fake enriched control region (CR) and applied to the signal region (SR).

Example: Contamination from fake τ_{had} in $2\ell\text{OS}{+}1\tau_{\text{had}}$:

A (SR T)

- 2ℓOS, $\geq$3 jets,
- $\geq$1 b-tagged jets,
- 1 τ_{had}(tight).

B (SR $\not{T}$)

- 2ℓOS, $\geq$3 jets,
- $\geq$1 b-tagged jets,
- 1 τ_{had}(anti-tight).

C (CR T)

- 2ℓOS, $\geq$3 jets,
- 0 b-tagged jets,
- 1 τ_{had}(tight).

D (CR $\not{T}$)

- 2ℓOS, $\geq$3 jets,
- 0 b-tagged jets,
- 1 τ_{had}(anti-tight).

$$\theta_{\tau_{\text{had}}} = \frac{N_C^{\text{fake}}}{N_D^{\text{fake}}} = \frac{N_C^{\text{data}} - N_C^{\text{prompt}}}{N_D^{\text{data}} - N_D^{\text{prompt}}} \longrightarrow N_A^{\text{fake}} = \theta_{\tau_{\text{had}}} \cdot N_B^{\text{fake}}$$

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Fake Factor Method

Systematic uncertainties include:

- statistical uncertainties in the CRs,
- uncertainties of the subtracted (N^{prompt}) background,
- definition of the CR,
- difference in the fake composition between CR and SR.

Both the CMS and ATLAS teams employ the Fake Factor (FF) method for the determination of fake-lepton contamination.

In ATLAS it is mostly used for the determination of fake τ_{had}:

1. $2\ell\mathrm{OS}+1\tau_{\mathrm{had}}$: fake e,μ MC, τ_{had} DD (FF),
2. $1\ell+2\tau_{\mathrm{had}}$: fake e,μ MC, τ_{had} DD (FF),
3. $3\ell+1\tau_{\mathrm{had}}$: fake e,μ MC, τ_{had} MC scaled to DD/MC of $2\ell\mathrm{OS}+1\tau_{\mathrm{had}}$,
4. $2\ell\mathrm{SS}+1\tau_{\mathrm{had}}$: fake e,μ DD (FF), τ_{had} MC scaled to DD/MC of $2\ell\mathrm{OS}+1\tau_{\mathrm{had}}$,

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Matrix Method

Similar to the Fake Factor method, but for pairs of leptons (CPPM).

$\epsilon_{\mathbf{r(f)}}$: **efficiency** of tight criteria on real (fake) leptons, measured in real (fake) lepton enriched regions.

then applied to the SR (before application of tight-criteria) to express the composition of tight (T) and anti-tight ($\not{T}$) events as:

SR application (simplified for 1 lepton):

$$\begin{aligned} N^T &= \epsilon_r N_r + \epsilon_f N_f \\ N^{\not{T}} &= \not{\epsilon}_r N_r + \not{\epsilon}_f N_f \end{aligned} \Rightarrow \begin{bmatrix} N^T \\ N^{\not{T}} \end{bmatrix} = \begin{bmatrix} \epsilon_r & \epsilon_f \\ \not{\epsilon}_r & \not{\epsilon}_r \end{bmatrix} \begin{bmatrix} N^r \\ N^f \end{bmatrix}$$

where $\not{\epsilon} \equiv 1 - \epsilon$.

N_r, N_f in the SR are obtained by inversion of the matrix, i.e.:

$$\begin{bmatrix} N^r \\ N^f \end{bmatrix} = \begin{bmatrix} \epsilon_r & \epsilon_f \\ \not{\epsilon}_r & \not{\epsilon}_r \end{bmatrix}^{-1} \begin{bmatrix} N^T \\ N^{\not{T}} \end{bmatrix}$$

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Matrix Method

Extension to 2 leptons. Here the order ij follows the order of p_{T}.

$$\begin{bmatrix} N^{TT} \\ N^{T\not T} \\ N^{\not T T} \\ N^{\not T \not T} \end{bmatrix} = \begin{bmatrix} \epsilon_r \epsilon_r & \epsilon_r \epsilon_f & \epsilon_f \epsilon_r & \epsilon_f \epsilon_f \\ \epsilon_r \not\epsilon_r & \epsilon_r \not\epsilon_f & \epsilon_f \not\epsilon_r & \epsilon_f \not\epsilon_f \\ \not\epsilon_r \epsilon_r & \not\epsilon_r \epsilon_f & \not\epsilon_f \epsilon_r & \not\epsilon_f \epsilon_f \\ \not\epsilon_r \not\epsilon_r & \not\epsilon_r \not\epsilon_f & \not\epsilon_f \not\epsilon_r & \not\epsilon_f \not\epsilon_f \end{bmatrix} \begin{bmatrix} N^{rr} \\ N^{rf} \\ N^{fr} \\ N^{ff} \end{bmatrix}$$

Most important systematic uncertainties are:

- uncertainties of the subtracted (N^{prompt}) background in the CRs,
- truth closure.

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Matrix Method

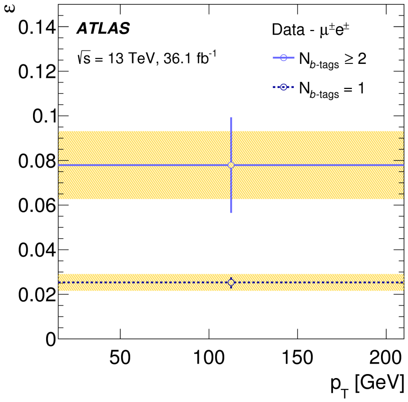

Figure: *electrons*

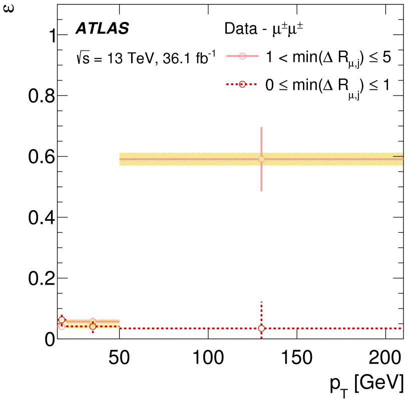

Figure: *muons*

Tight selection efficiencies for loose fake and non-prompt leptons, as measured in data control regions. Parameterization in $[p_{\mathrm{T}}, N_{b-\mathrm{tags}}]$ for electrons, $[p_{\mathrm{T}}, \min\Delta R(\mu, \mathrm{jet})]$ for muons.

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Electron charge-flip background

Mis-identification of the electron charge sign:

- Hard Bremsstrahlung$\rightarrow$ photon conversion, where the wrong charge electron inherits the largest p_{T} fraction.
- mis-reconstruction of the electron charge due to small track curvature in the inner detector (dominant at high p_{T}).

$\Rightarrow$ Contamination from OS events (predominantly $t\bar{t}$).

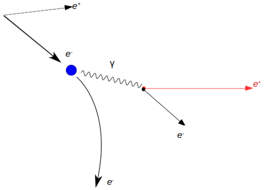

Figure: *Tight electron charge-flip rates.*

ϵ: rate of charge-flipped electrons is measured from the ratio of $Z \rightarrow ee$ events, reconstructed with opposite (N^{OS}) and same-sign charge (N^{SS}).

$$\epsilon = \frac{N^{\mathrm{SS}}}{2N^{\mathrm{OS}}}$$

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Electron charge-flip background

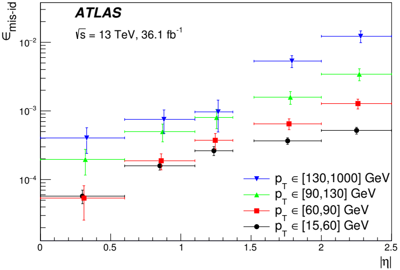
Parameterisation:

$\vec{\epsilon}$: rates obtained in bins of p_T, η (2D).
Loose electrons can be used (3D) to improve the statistics with "tight/loose" combinations (LPC) .

Bin correlations are described in a profile Likelihood, maximised with respect to $\vec{\epsilon}$.

Uncertainties:

- statistical errors (LH);
- definition of Z mass window;
- truth closure;



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Electron charge-flip background

The contamination in the SR (N^{BG}) is estimated from the reconstructed OS data events (N^{OS}) passing SR criteria (except the SS requirement).

- For OS $e\mu/\mu e$ events, where e falls in bin i, the **dilepton** charge-flip rate is equal to the flip rate of the electron (ϵ_i) $\Rightarrow$

$$N_i^{\mathrm{BG}} = \frac{\epsilon_i}{1-\epsilon_i} N_i^{\mathrm{OS}}$$

- For e^-e^+ events, falling in ij, the **dielectron** charge-flip rate is the XOR of the individual flip rates (ϵ_i, ϵ_j) $\Rightarrow$

$$\epsilon_{ij}^{\mathrm{SS}} = \epsilon_i + \epsilon_j - \epsilon_i \epsilon_j$$

$$N_{ij}^{\mathrm{BG}} = \frac{\epsilon_{ij}^{\mathrm{SS}}}{1-\epsilon_{ij}^{\mathrm{SS}}} N_{ij}^{\mathrm{OS}}$$

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Conclusions

- Background estimation is a crucial aspect to the $t\bar{t}H \rightarrow$ multilepton search.
- Common approaches, presented above, are used by both ATLAS and CMS teams for the measurement of non-prompt lepton contamination (LPC, CPPM, LPSC).
- In conjunction with robust background rejection techniques (CPPM, LPSC, IPHC, IPNL) we hope for a prompt discovery of the $t\bar{t}H$ final state by both experiments.

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Backup

Background Yield (ATLAS)

Category	Non-prompt	Fake τ_{had}	q mis-id	$t\bar{t}W$	$t\bar{t}Z$	Diboson	Other	Total Bkgd.	$t\bar{t}H$	Observed
					Pre-fit yields					
2ℓSS	233 ± 39	–	33 ± 11	123 ± 18	41.4 ± 5.6	25 ± 15	28.4 ± 5.9	484 ± 38	42.6 ± 4.2	514
3ℓ SR	14.5 ± 4.3	–	–	5.5 ± 1.2	12.0 ± 1.8	1.2 ± 1.2	5.8 ± 1.4	39.1 ± 5.2	11.2 ± 1.6	61
3ℓ $t\bar{t}W$ CR	13.3 ± 4.3	–	–	19.9 ± 3.1	8.7 ± 1.1	< 0.2	4.53 ± 0.92	46.5 ± 5.4	4.18 ± 0.46	56
3ℓ $t\bar{t}Z$ CR	3.9 ± 2.5	–	–	2.71 ± 0.56	66 ± 11	8.4 ± 5.3	12.9 ± 4.2	93 ± 13	3.17 ± 0.41	107
3ℓ VV CR	27.7 ± 8.7	–	–	4.9 ± 1.0	21.3 ± 3.4	51 ± 30	17.9 ± 6.1	123 ± 32	1.67 ± 0.25	109
3ℓ $t\bar{t}$ CR	70 ± 17	–	–	10.5 ± 1.5	7.9 ± 1.1	7.2 ± 4.8	7.3 ± 1.9	103 ± 17	4.00 ± 0.49	85
4ℓ Z-enr.	0.11 ± 0.07	–	–	< 0.01	1.52 ± 0.23	0.43 ± 0.23	0.21 ± 0.09	2.26 ± 0.34	1.06 ± 0.14	2
4ℓ Z-dep.	0.01 ± 0.01	–	–	< 0.01	0.04 ± 0.02	< 0.01	0.06 ± 0.03	0.11 ± 0.03	0.20 ± 0.03	0
$1\ell+2\tau_{had}$	–	65 ± 21	–	0.09 ± 0.09	3.3 ± 1.0	1.3 ± 1.0	0.98 ± 0.35	71 ± 21	4.3 ± 1.0	67
2ℓSS$+1\tau_{had}$	2.4 ± 1.4	1.80 ± 0.30	0.05 ± 0.02	0.88 ± 0.24	1.83 ± 0.37	0.12 ± 0.18	1.06 ± 0.24	8.2 ± 1.6	3.09 ± 0.46	18
2ℓOS$+1\tau_{had}$	–	756 ± 80	–	6.5 ± 1.3	11.4 ± 1.9	2.0 ± 1.3	5.8 ± 1.5	782 ± 81	14.2 ± 2.0	807
$3\ell+1\tau_{had}$	–	0.75 ± 0.15	–	0.04 ± 0.04	1.38 ± 0.24	0.002 ± 0.002	0.38 ± 0.10	2.55 ± 0.32	1.51 ± 0.23	5
					Post-fit yields					
2ℓSS	211 ± 26	–	28.3 ± 9.4	127 ± 18	42.9 ± 5.4	20.0 ± 6.3	28.5 ± 5.7	459 ± 24	67 ± 18	514
3ℓ SR	13.2 ± 3.1	–	–	5.8 ± 1.2	12.9 ± 1.6	1.2 ± 1.1	5.9 ± 1.3	39.0 ± 4.0	17.7 ± 4.9	61
3ℓ $t\bar{t}W$ CR	11.7 ± 3.0	–	–	20.4 ± 3.0	8.9 ± 1.0	< 0.2	4.54 ± 0.88	45.6 ± 4.0	6.6 ± 1.9	56
3ℓ $t\bar{t}Z$ CR	3.5 ± 2.1	–	–	2.82 ± 0.56	70.4 ± 8.6	7.1 ± 3.0	13.6 ± 4.2	97.4 ± 8.6	5.1 ± 1.4	107
3ℓ VV CR	22.4 ± 5.7	–	–	5.05 ± 0.94	22.0 ± 3.0	39 ± 11	18.1 ± 5.9	106.8 ± 9.4	2.61 ± 0.82	109
3ℓ $t\bar{t}$ CR	56.0 ± 8.1	–	–	10.7 ± 1.4	8.1 ± 1.0	5.9 ± 2.7	7.1 ± 1.8	87.8 ± 7.9	6.3 ± 1.8	85
4ℓ Z-enr.	0.10 ± 0.07	–	–	< 0.01	1.60 ± 0.22	0.37 ± 0.15	0.22 ± 0.10	2.29 ± 0.28	1.65 ± 0.47	2
4ℓ Z-dep.	0.01 ± 0.01	–	–	< 0.01	0.04 ± 0.02	< 0.01	0.07 ± 0.03	0.11 ± 0.03	0.32 ± 0.09	0
$1\ell+2\tau_{had}$	–	58.0 ± 6.8	–	0.11 ± 0.11	3.31 ± 0.90	0.98 ± 0.75	0.98 ± 0.33	63.4 ± 6.7	6.5 ± 2.0	67
2ℓSS$+1\tau_{had}$	1.86 ± 0.91	1.86 ± 0.27	0.05 ± 0.02	0.97 ± 0.26	1.96 ± 0.37	0.15 ± 0.20	1.09 ± 0.24	7.9 ± 1.2	5.1 ± 1.3	18
2ℓOS$+1\tau_{had}$	–	756 ± 28	–	6.6 ± 1.3	11.5 ± 1.7	1.64 ± 0.92	6.1 ± 1.5	782 ± 27	21.7 ± 5.9	807
$3\ell+1\tau_{had}$	–	0.75 ± 0.14	–	0.04 ± 0.04	1.42 ± 0.22	0.002 ± 0.002	0.40 ± 0.10	2.61 ± 0.30	2.41 ± 0.68	5

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Background Yield (CMS)

Process	$1\ell + 2\tau_h$	$2\ell ss$	$2\ell ss + 1\tau_h$
$t\bar{t}H$	5.8 ± 1.9	53.8 ± 17.0	9.4 ± 2.8
$t\bar{t}Z/\gamma^*$	6.3 ± 1.1	80.9 ± 10.4	9.2 ± 1.2
$t\bar{t}W + t\bar{t}WW$	0.5 ± 0.1	150.0 ± 16.9	9.1 ± 1.0
$WZ + ZZ$	2.1 ± 1.6	16.5 ± 13.1	3.9 ± 3.0
tH	0.4 ± 0.1	2.7 ± 0.2	0.5 ± 0.04
Conversions	< 0.02	12.1 ± 5.8	1.4 ± 0.5
Sign flip	—	27.5 ± 8.0	0.5 ± 0.1
Misidentified leptons	195.7 ± 13.6	94.2 ± 21.2	8.6 ± 2.1
Rare backgrounds	1.4 ± 0.7	39.0 ± 21.2	3.1 ± 1.5
Total expected background	206.3 ± 14.0	423.0 ± 38.0	36.1 ± 4.2
Observed	212	507	49

Process	3ℓ	$3\ell + 1\tau_h$	4ℓ
$t\bar{t}H$	18.5 ± 6.0	2.1 ± 0.7	0.9 ± 0.3
$t\bar{t}Z/\gamma^*$	49.0 ± 6.9	3.4 ± 0.5	2.1 ± 0.4
$t\bar{t}W + t\bar{t}WW$	35.2 ± 4.2	0.4 ± 0.04	$< 2 \times 10^{-3}$
$WZ + ZZ$	9.9 ± 2.4	0.3 ± 0.05	0.1 ± 0.1
tH	1.2 ± 0.2	0.1 ± 0.01	$< 4 \times 10^{-4}$
Conversions	5.3 ± 2.9	< 0.02	< 0.02
Misidentified leptons	22.7 ± 6.7	0.9 ± 0.2	< 0.04
Rare backgrounds	8.2 ± 13.8	0.2 ± 0.1	0.1 ± 0.2
Total expected background	131.4 ± 18.2	5.3 ± 0.5	2.4 ± 0.4
Observed	148	7	3

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Signal Region definitions(ATLAS)

Channel	Selection criteria
Common	$N_{\text{jets}} \geq 2$ and $N_{b\text{-jets}} \geq 1$
2ℓSS	Two very tight light leptons with $p_T > 20$ GeV Same-charge light leptons Zero medium τ_{had} candidates $N_{\text{jets}} \geq 4$ and $N_{b\text{-jets}} < 3$
3ℓ	Three light leptons with $p_T > 10$ GeV; sum of light-lepton charges ± 1 Two same-charge leptons must be very tight and have $p_T > 15$ GeV The opposite-charge lepton must be loose, isolated and pass the non-prompt BDT Zero medium τ_{had} candidates $m(\ell^+\ell^-) > 12$ GeV and $\lvert m(\ell^+\ell^-) - 91.2\text{ GeV}\rvert > 10$ GeV for all SFOC pairs $\lvert m(3\ell) - 91.2\text{ GeV}\rvert > 10$ GeV
4ℓ	Four light leptons; sum of light-lepton charges 0 Third and fourth leading leptons must be tight $m(\ell^+\ell^-) > 12$ GeV and $\lvert m(\ell^+\ell^-) - 91.2\text{ GeV}\rvert > 10$ GeV for all SFOC pairs $\lvert m(4\ell) - 125\text{ GeV}\rvert > 5$ GeV Split 2 categories: Z-depleted (0 SFOC pairs) and Z-enriched (2 or 4 SFOC pairs)
$1\ell+2\tau_{\text{had}}$	One tight light lepton with $p_T > 27$ GeV Two medium τ_{had} candidates of opposite charge, at least one being tight $N_{\text{jets}} \geq 3$
$2\ell\text{SS}+1\tau_{\text{had}}$	Two very tight light leptons with $p_T > 15$ GeV Same-charge light leptons One medium τ_{had} candidate, with charge opposite to that of the light leptons $N_{\text{jets}} \geq 4$ $\lvert m(ee) - 91.2\text{ GeV}\rvert > 10$ GeV for ee events
$2\ell\text{OS}+1\tau_{\text{had}}$	Two loose and isolated light leptons with $p_T > 25, 15$ GeV One medium τ_{had} candidate Opposite-charge light leptons One medium τ_{had} candidate $m(\ell^+\ell^-) > 12$ GeV and $\lvert m(\ell^+\ell^-) - 91.2\text{ GeV}\rvert > 10$ GeV for the SFOC pair $N_{\text{jets}} \geq 3$
$3\ell+1\tau_{\text{had}}$	3ℓ selection, except: One medium τ_{had} candidate, with charge opposite to the total charge of the light leptons The two same-charge light leptons must be tight and have $p_T > 10$ GeV The opposite-charge light lepton must be loose and isolated

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Trigger requirements (ATLAS)

- Single-electron(muon) trigger:
  2015: $p_{\mathrm{T}} > 24$ (20) GeV.
  2016: $p_{\mathrm{T}} > 26$ GeV.
- Double-lepton triggers:
  2015 (2016): 12+12 (17+17) GeV for dielectron;
  2015 (2016): 18+8 (22+8) GeV for dimuon.
- Electron+muon: 17+14 GeV.

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Control Region definitions(ATLAS)

Channel	Region	Selection criteria
2ℓSS		$2 \leq N_{\text{jets}} \leq 3$ and $N_{b\text{-jets}} \geq 1$
(3ℓ)		One very tight, one loose light lepton with $p_T > 20$ (15) GeV
		Zero τ_{had} candidates
	ϵ_{real}	Opposite charge; opposite flavor
	ϵ_{fake}	Same charge; opposite flavor or $\mu\mu$
4ℓ		$1 \leq N_{\text{jets}} \leq 2$
		Three loose light leptons; sum of light lepton charges ± 1
		Subleading same-charge lepton must be tight
		Veto on 3ℓ selection
	Either	One SFOC pair with $\lvert m(\ell^+\ell^-) - 91.2\text{ GeV}\rvert < 10$ GeV
		$E_T^{\text{miss}} < 50$ GeV, $m_T < 50$ GeV
	or	No SFOC pair
		Subleading jet $p_T > 30$ GeV
2ℓSS+$1\tau_{\text{had}}$		$2 \leq N_{\text{jets}} \leq 3$ and $N_{b\text{-jets}} \geq 1$
		One very tight, one loose light lepton with $p_T > 15$ GeV
		A SFSC pair
		$\lvert m(ee) - 91.2\text{ GeV}\rvert > 10$ GeV
		Zero or one medium τ_{had} candidate, opposite in charge to the light leptons
1ℓ+$2\tau_{\text{had}}$		$N_{\text{jets}} \geq 3$ and $N_{b\text{-jets}} \geq 1$
		One tight light lepton, with $p_T > 27$ GeV
		Two τ_{had} candidates of same charge
		At least one τ_{had} candidate has to satisfy tight identification criteria
2ℓOS+$1\tau_{\text{had}}$		Two loose and isolated light leptons, with $p_T > 25$, 15 GeV
		One loose τ_{had} candidate
		$\lvert m(\ell^+\ell^-) - 91.2\text{ GeV}\rvert > 10$ GeV and $m(\ell^+\ell^-) > 12$ GeV
		$N_{\text{jets}} \geq 3$ and $N_{b\text{-jets}} = 0$

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Non-prompt-lepton BDT efficiency (ATLAS)

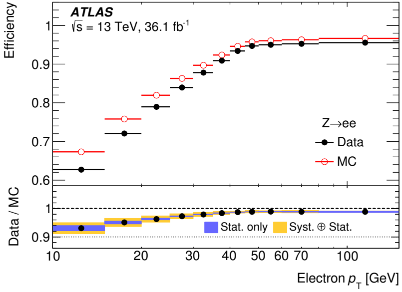

Figure: *electrons*

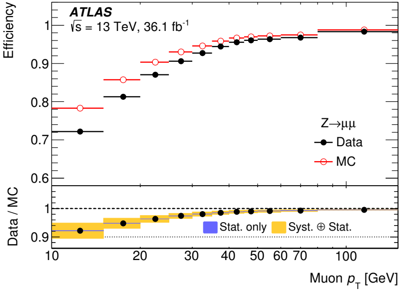

Figure: *muons*

The efficiency to select well-identified prompt muons (left) and electrons (right) at the chosen non-prompt lepton BDT working point, as a function of the lepton p_{T}.

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