Search for Exotic Phenomena Using Events with Same Charge Dileptons + b-Jets at 13 TeV with ATLAS

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on behalf of the ATLAS Collaboration

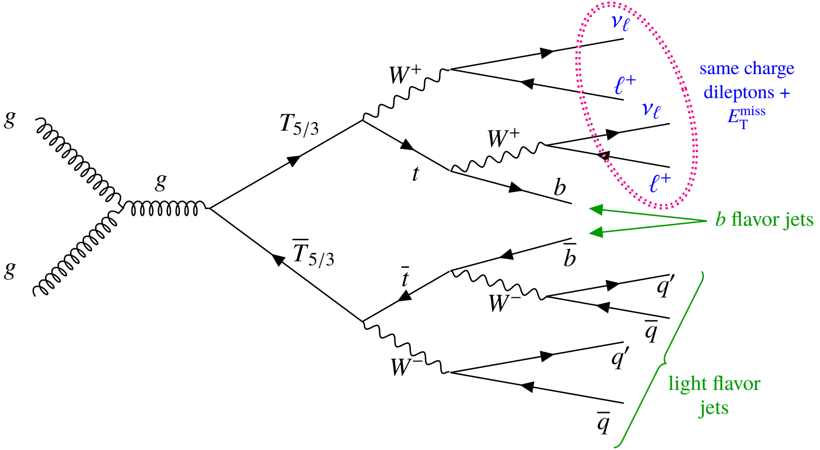
Recontres de Moriond Electroweak 2017
Young Scientist Forum

ATLAS EXPERIMENT

THE UNIVERSITY OF ARIZONA®

Motivations for Search

- Standard Model backgrounds are low ($t\bar{t}+V$, Diboson, etc.)
- A variety of new and exotic physics can lead to our final state of interest, our focus is:
  → **Vector-Like** T, B, and $T_{5/3}$ pair production (more on this in tomorrow's BSM II)
  → **4-top** $t\bar{t}t\bar{t}$ production via: contact interaction (C_{4t}/Λ^2), SM, and 2UED/RPP model

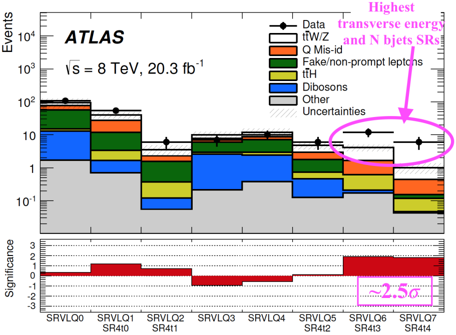


General strategy is cut-and-count

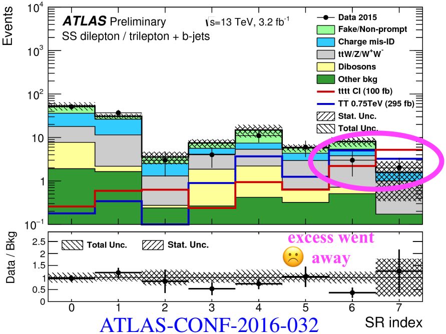
Run II priorities

- **Early Run II dataset (2015 ~ 3.2 fb^{-1}):** check same signal regions for slight excess found in Run I (*plots shown in this talk are from this set of data*)
  → no excess in Run II found so far
- **Full Run II dataset (2015+2016 ~ 36.1 fb^{-1}):** in progress, optimizing selections, data-driven background estimations, and signal regions

(NB: H_T = scalar sum of lepton + jet p_T)



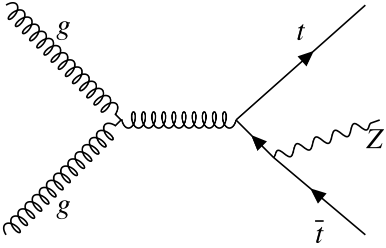
JHEP 2015

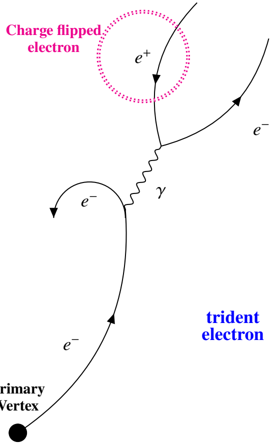


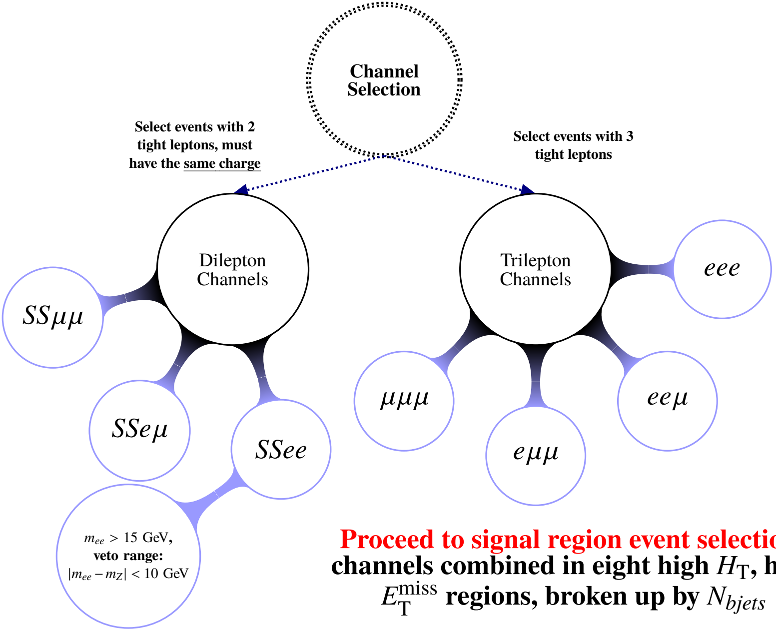
ATLAS-CONF-2016-032

Three major backgrounds:

- **Irreducible:** SM processes that produce real pairs of same-sign leptons and corresponding jets
  → Estimated with **MC**
- **Fake/non-prompt leptons:** leptons fakes by heavy flavored jets (most likely b-jets) or originating from sources other than hard scatter
  → Estimated with **data**
- **Charge mis-id:** charge mis-measured for electrons
  → Negligible for muons
  → Estimated with **data**

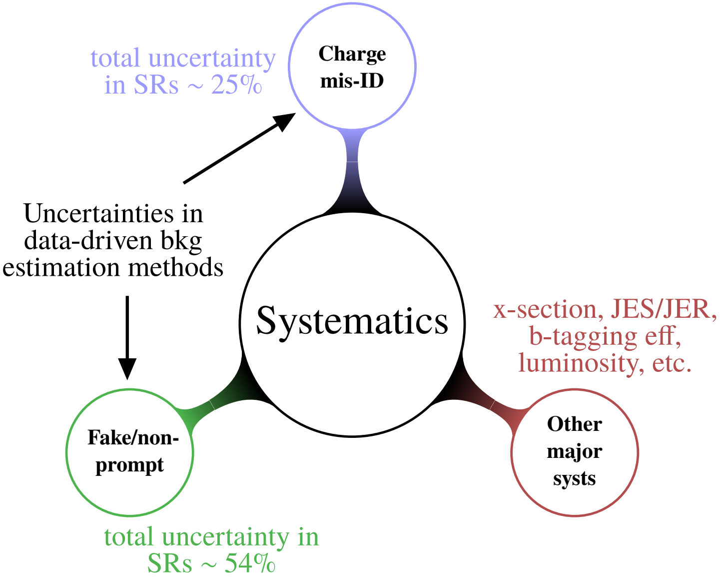




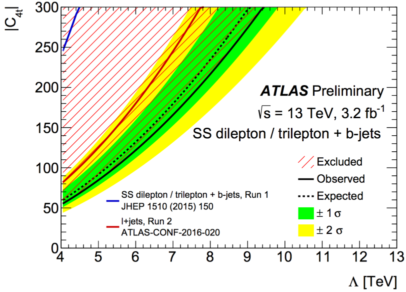


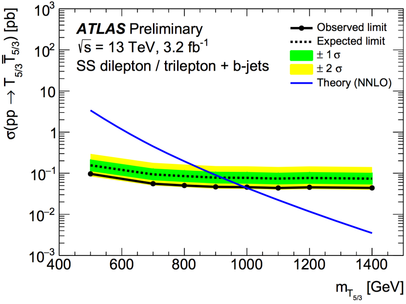
Proceed to signal region event selection:
channels combined in eight high H_{T}, high $E_{\mathrm{T}}^{\mathrm{miss}}$ regions, broken up by N_{bjets}

Major Systematic Uncertainties

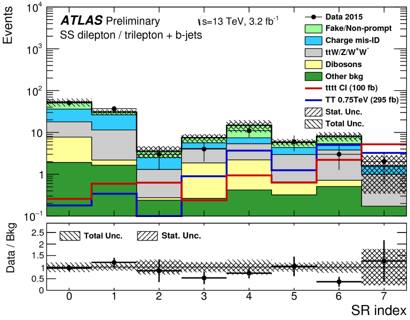


Results





- Modest excess from Run I unconfirmed so far in Run II
- 95% CL limits set on various signal models:
  $\rightarrow |C_{4t}|/\Lambda^2 > 3.5$ TeV^{-2}
  (shown left top)
  $\rightarrow m_{T_{5/3}} > 0.99$ TeV (pair prod. limit only)
  (shown left bottom)
  $\rightarrow m_{VLB} > 0.83$ TeV, $m_{VLT} > 0.78$ TeV
  $\rightarrow m_{KK} > 1.4$ TeV



Both systematic and statistical uncertainties are shown.

Thank you!

BACKUPS

Production of Vector Like Quarks

Pair production modes

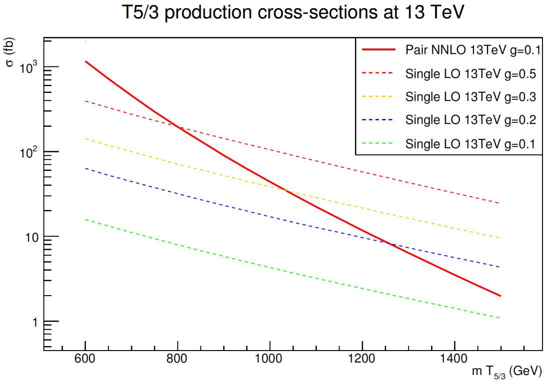
$$gg, q\bar{q} \longrightarrow Q\bar{Q}$$

where $Q = T, B, T_{5/3}, B_{-4/3}$

Single production modes

$$gq \rightarrow T\bar{b}q',$$
$$gq \rightarrow B(B_{-4/3})\bar{b}q(q'),$$
$$gq \rightarrow T(T_{5/3})\bar{t}q'$$

where q and q' are light jets



- **SS+b-Jets Analysis:** focuses on T, B pair production and $T_{5/3}$ pair and single production
  → Sensitivity to same-charge leptons in the final state is higher

Signal Region Definitions

Definition			Name
$e^{\pm}e^{\pm} + e^{\pm}\mu^{\pm} + \mu^{\pm}\mu^{\pm} + eee + ee\mu + e\mu\mu + \mu\mu\mu,\ N_j \geq 2$			
$400 < H_{\mathrm{T}} < 700$ GeV	$N_b = 1$	$E_{\mathrm{T}}^{\mathrm{miss}} > 40$ GeV	SR0
	$N_b = 2$		SR1
	$N_b \geq 3$		SR2
$H_{\mathrm{T}} \geq 700$ GeV	$N_b = 1$	$40 < E_{\mathrm{T}}^{\mathrm{miss}} < 100$ GeV	SR3
		$E_{\mathrm{T}}^{\mathrm{miss}} \geq 100$ GeV	SR4
	$N_b = 2$	$40 < E_{\mathrm{T}}^{\mathrm{miss}} < 100$ GeV	SR5
		$E_{\mathrm{T}}^{\mathrm{miss}} \geq 100$ GeV	SR6
	$N_b \geq 3$	$E_{\mathrm{T}}^{\mathrm{miss}} > 40$ GeV	SR7

- These are being re-optimized for use with the full 2015+2016 dataset

Systematic Uncertainties

Largest systematics on total background:

Source	Signal region							
	SR0	SR1	SR2	SR3	SR4	SR5	SR6	SR7
Cross section	8	11	26	13	9	27	23	57
Jet energy scale	1	1	3	1	1	3	2	4
Jet energy resolution	<1	2	2	2	< 1	1	<1	3
b-tagging efficiency	1	2	5	3	1	2	2	7
Luminosity	1	1	1	1	1	1	1	1
Fake/non-prompt leptons	17	7	15	13	26	13	17	17
Charge misID	8	3	7	5	3	6	5	8

Largest systematics for typical signal (4-top SM)

Source	Signal region							
	SR0	SR1	SR2	SR3	SR4	SR5	SR6	SR7
Jet energy scale	2	12	2	6	4	3	3	3
Jet energy resolution	16	6	7	16	14	11	1	2
b-tagging efficiency	8	5	5	21	14	15	5	5
Lepton ID efficiency	1	1	1	4	2	2	2	1
Luminosity	2	2	2	2	2	2	2	2

Backgrounds: Fake/Non-Prompt

Leptons can be faked by heavy and light flavor jets (most often from *b*-jets)
Leptons can be non-prompt if they don't originate from primary hard-scatter

Estimated using: **Matrix Method**

$$\begin{pmatrix} N_{tt} \\ N_{t\bar{t}} \\ N_{\bar{t}t} \\ N_{\bar{t}\bar{t}} \end{pmatrix} = \mathbf{M} \begin{pmatrix} N^{ll}_{rr} \\ N^{ll}_{fr} \\ N^{ll}_{rf} \\ N^{ll}_{ff} \end{pmatrix}, \mathbf{M} \equiv \begin{pmatrix} r_1 r_2 & r_1 f_2 & f_1 r_2 & f_1 f_2 \\ r_1 \overline{r_2} & r_1 \overline{f_2} & f_1 \overline{r_2} & f_1 \overline{f_2} \\ \overline{r_1} r_2 & \overline{r_1} f_2 & \overline{f_1} r_2 & \overline{f_1} f_2 \\ \overline{r_1}\,\overline{r_2} & \overline{r_1}\,\overline{f_2} & \overline{f_1}\,\overline{r_2} & \overline{f_1}\,\overline{f_2} \end{pmatrix}$$

Select control region enriched in either *fake* or *real* leptons

loose lepton sample

tight sample (isolated leptons)

$$f\,(r) = \frac{N^{fake(real)}_{tight}}{N^{fake(real)}_{loose}}$$

- **Calculate** r **and** f, parameterized by lepton p_{T}, η, and $\Delta R_{\mathrm{min}}(\ell, \mathrm{jet})$
- **Invert matrix** M and calculate N tight leptons that are fake
- **Likelihood Matrix Method** used for stability in calculation

These backgrounds are modeled with **data**

Poisson Likelihood Matrix Method

Apply r and f to the ***loose*** sample, use Matrix Method to calculate number of ***fake*** leptons in the ***tight*** sample

$$L = P(N^{tt}, N^{tt}_{\text{pred}})P(N^{t\bar{t}}, N^{t\bar{t}}_{\text{pred}})P(N^{\bar{t}t}, N^{\bar{t}t}_{\text{pred}})P(N^{\bar{t}\bar{t}}, N^{\bar{t}\bar{t}}_{\text{pred}})$$

$$N^{tt}_{\text{fake}} = N^{tt}_{rf} + N^{tt}_{fr} + N^{tt}_{ff}$$

$$N^{tt}_{\text{pred}} = N^{tt}_{rr} + N^{tt}_{rf} + N^{tt}_{fr} + N^{tt}_{ff}$$

$$N^{t\bar{t}}_{\text{pred}} = \frac{\langle r_1\tilde{r}_2\rangle}{\langle r_1 r_2\rangle}N^{tt}_{rr} + \frac{\langle r_1\tilde{f}_2\rangle}{\langle r_1 f_2\rangle}N^{tt}_{rf} + \frac{\langle f_1\tilde{r}_2\rangle}{\langle f_1 r_2\rangle}N^{tt}_{fr} + \frac{\langle f_1\tilde{f}_2\rangle}{\langle f_1 f_2\rangle}N^{tt}_{ff}$$

$$N^{\bar{t}t}_{\text{pred}} = \frac{\langle \tilde{r}_1 r_2\rangle}{\langle r_1 r_2\rangle}N^{tt}_{rr} + \frac{\langle \tilde{r}_1 f_2\rangle}{\langle r_1 f_2\rangle}N^{tt}_{rf} + \frac{\langle \tilde{f}_1 r_2\rangle}{\langle f_1 r_2\rangle}N^{tt}_{fr} + \frac{\langle \tilde{f}_1 f_2\rangle}{\langle f_1 f_2\rangle}N^{tt}_{ff}$$

$$N^{\bar{t}\bar{t}}_{\text{pred}} = \frac{\langle \tilde{r}_1\tilde{r}_2\rangle}{\langle r_1 r_2\rangle}N^{tt}_{rr} + \frac{\langle \tilde{r}_1\tilde{f}_2\rangle}{\langle r_1 f_2\rangle}N^{tt}_{rf} + \frac{\langle \tilde{f}_1\tilde{r}_2\rangle}{\langle f_1 r_2\rangle}N^{tt}_{fr} + \frac{\langle \tilde{f}_1\tilde{f}_2\rangle}{\langle f_1 f_2\rangle}N^{tt}_{ff}$$

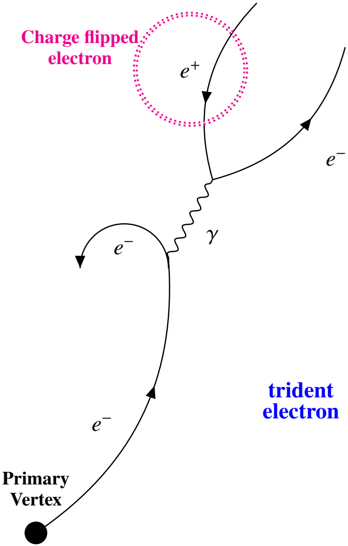
Lepton charge can be mis-measured

- Only measured for electrons[1]

Estimated using likelihood minimization

- Parametrized in electron p_{T} and $|\eta_{clus}|$
- Estimation of charge flip-rate in 'Z-peak' region: $|m_{ee} - m_Z| < 10$ GeV using $Z \to ee$ events (no charge requirement)
- Apply event weight, w, on electrons in events matching signal region selection, but requiring *opposite sign* pairs

$$w = \frac{\varepsilon_1 + \varepsilon_2 - 2\varepsilon_1\varepsilon_2}{1 - (\varepsilon_1 + \varepsilon_2 - 2\varepsilon_1\varepsilon_2)}$$



These backgrounds are modeled with **data**

[1] Muon charge is measured in both ID and MS, the ATLAS Muon system has a long lever arm, and muons have a small probability of radiating a photon