Search for light stop pair production in final states with leptons and b-jets with the ATLAS detector

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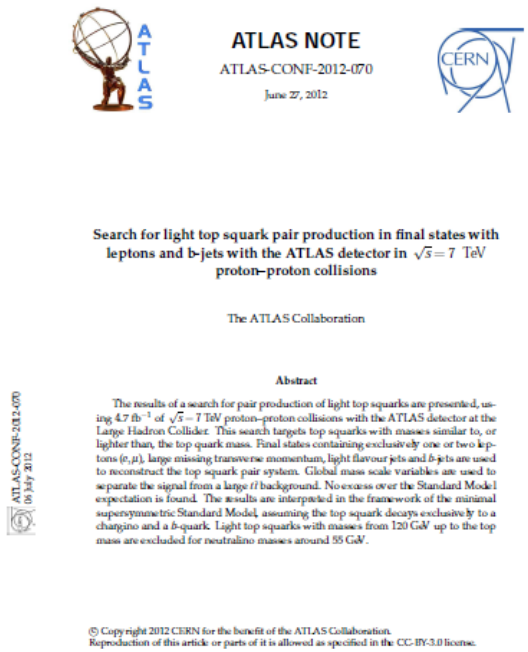
Outline



ATLAS NOTE
ATLAS-CONF-2012-070
June 27, 2012

Search for light top squark pair production in final states with leptons and b-jets with the ATLAS detector in $\sqrt{s} = 7$ TeV proton–proton collisions

The ATLAS Collaboration

Abstract

The results of a search for pair production of light top squarks are presented, using 4.7 fb^{-1} of $\sqrt{s} = 7$ TeV proton–proton collisions with the ATLAS detector at the Large Hadron Collider. This search targets top squarks with masses similar to, or lighter than, the top quark mass. Final states containing exclusively one or two leptons (e, μ), large missing transverse momentum, light flavour jets and b-jets are used to reconstruct the top squark pair system. Global mass scale variables are used to separate the signal from a large $t\bar{t}$ background. No excess over the Standard Model expectation is found. The results are interpreted in the framework of the minimal supersymmetric Standard Model, assuming the top squark decays exclusively to a chargino and a b-quark. Light top squarks with masses from 120 GeV up to the top mass are excluded for neutralino masses around 55 GeV.

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Introduction

- ✓ Direct stop pair production in MSSM context
  - Stop as the lightest squark
  - Other squark and gluino masses at TeV order
- ✓ Addressed mass range 130 - 200 GeV
- ✓ Assumed mass hierarchy:
  - $m(\tilde{\chi}_1^{\pm}) < m(\tilde{t}) - m(b) \Longrightarrow \tilde{t} \to \tilde{\chi}_1^{\pm} b$
  - $m(\tilde{\ell})$ TeV order $\Longrightarrow \tilde{\chi}_1^{\pm} \to W^{(*)} \tilde{\chi}_1^0$
- ✓ Three scan of the parameter space:
  - $(m_{\tilde{t}}, m_{\tilde{\chi}_1^0})$, assuming $m(\tilde{\chi}_1^{\pm}) = 2(\tilde{\chi}_1^0)$
  - $(m_{\tilde{\chi}_1^{\pm}}, m_{\tilde{\chi}_1^0})$, for $m(\tilde{t}) = 180$ GeV
  - $(m_{\tilde{t}}, m_{\tilde{\chi}_1^0})$, for $m(\tilde{\chi}_1^{\pm}) = 105.8$ GeV

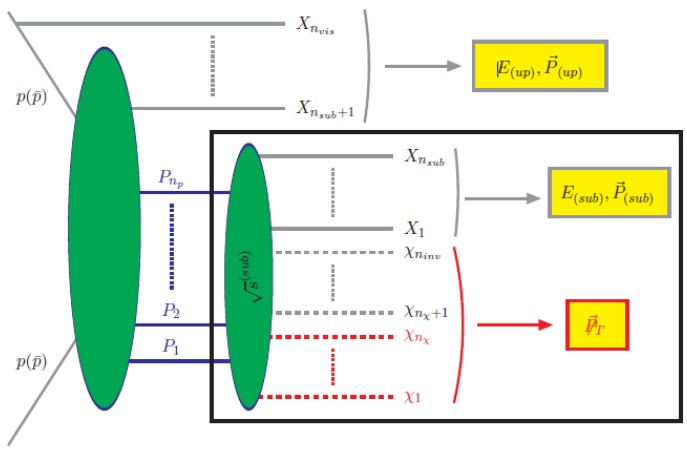
General Strategy

$$\tilde{t} \rightarrow \tilde{\chi}_1^{\pm} b \rightarrow W^{(*)} \tilde{\chi}_1^0 b$$

Two final states considered

- Semileptonic decay $\longrightarrow$ 2 b-jets, 2 jets, 1 lepton, $E_{\mathrm{T}}^{\mathrm{miss}}$ 1 lepton analysis
- Dileptonic decay $\longrightarrow$ 2 b-jets, 2 OS leptons, $E_{\mathrm{T}}^{\mathrm{miss}}$ 2 leptons analysis

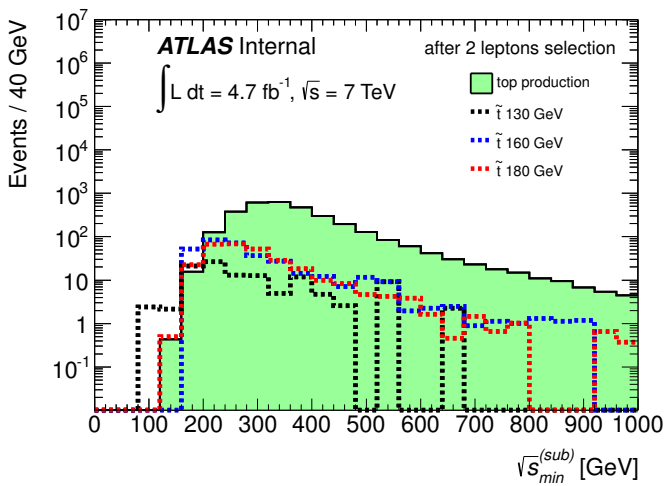
- Searched signal same topology as $t\bar{t}$
- Stop decay product softer than top ones
- Key discriminating variable $\sqrt{s}_{min}^{(sub)}$ (http://arxiv.org/abs/1006.0653v1)
- Reconstruct minimum mass energy compatible with a subsystem



General Strategy (2)

$$\sqrt{s}_{min}^{(sub)}(\not{M}) = \left\{ \left(\sqrt{M_{(sub)}^2 + P_{T(sub)}^2} + \sqrt{\not{M}^2 + \not{P}_T^2} \right)^2 - \left(\vec{P}_{T(sub)} + \vec{\not{P}}_T \right)^2 \right\}^{\frac{1}{2}}$$

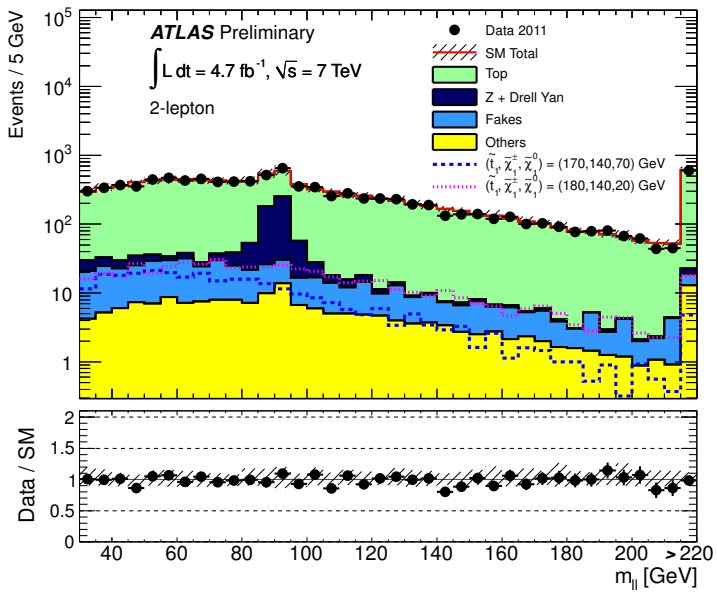
- Minimum mass energy compatible with a subsystem
- For $t\bar{t}$ should peak at $2m(t)$
- $\not{M} = 0$ for $t\bar{t} \Rightarrow$ discriminat signal and background

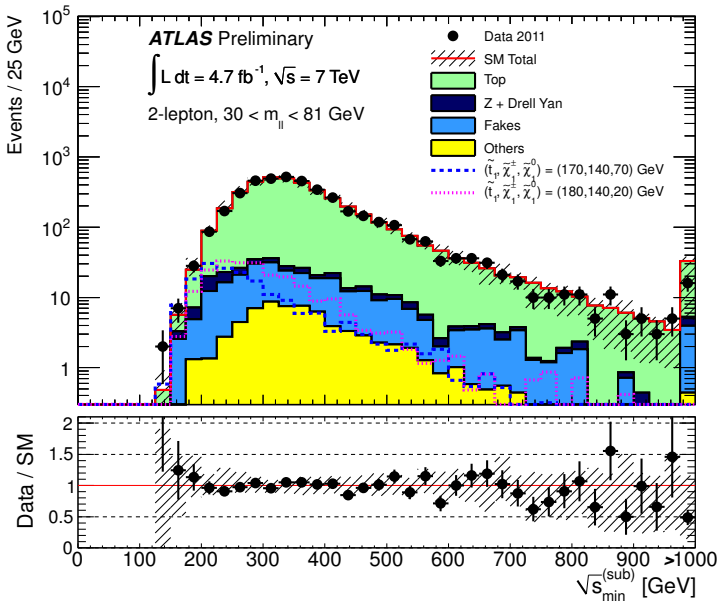


Events Selection

- ✓ Full 2011 dataset (7 TeV), $4.7 fb^{-1}$
- ✓ Events must contain the minimum number of objects of dileptonic $t\bar{t}$ decay
  - At least two jets, one b-tagged
  - Two opposite sign signal leptons
    - Two electrons: $p_T > 25, 20$ GeV
    - Two muons: $p_T > 20, 10$ GeV
    - One electron one muon: either electron $p_T > 25$ or muon $p_T > 20$ GeV
  - $E_{\mathrm{T}}^{\mathrm{miss}} > 40$ GeV
- ✓ Split in three $m_{\ell\ell}$ regions
  - Signal region: $30 < m_{\ell\ell} < 81$ GeV
  - Z control region: $81 < m_{\ell\ell} < 101$ GeV, same flavour leptons
  - $t\bar{t}$ control region: $m_{\ell\ell} > 101$ GeV
- ✓ Final selection on $\sqrt{s}_{min}^{(sub)}$ and m(lljj) variables
  - Signal region 1 $\sqrt{s}_{min}^{(sub)} < 225$ GeV
  - Signal region 2 $\sqrt{s}_{min}^{(sub)} < 235$ GeV and m(lljj) < 140 GeV

Distributions

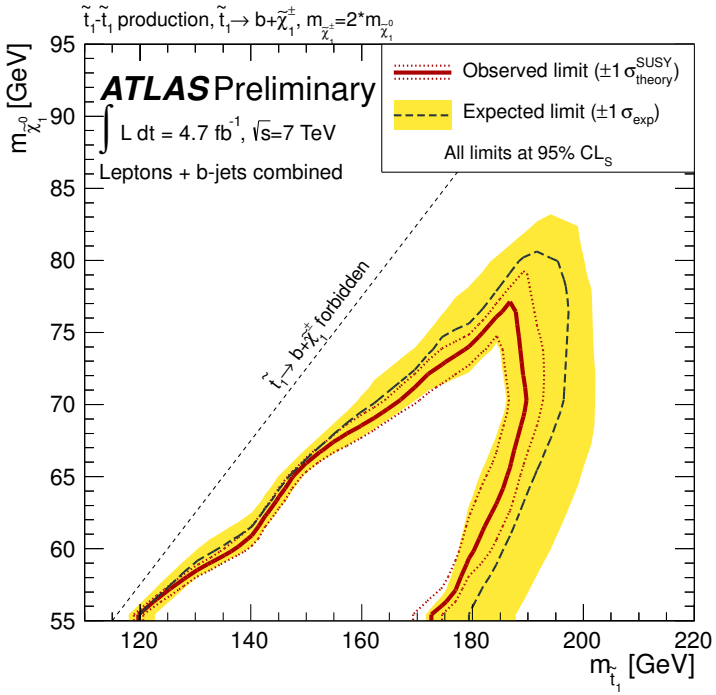


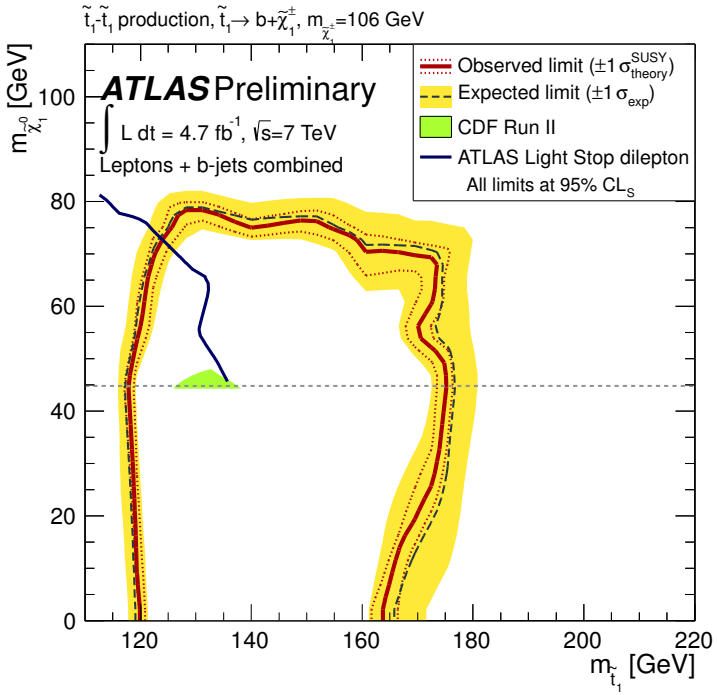


Results

	Number of events		
Process	1L SR	2L SR1	2L SR2
Top	$24 \pm 3 \pm 5$	$89 \pm 6 \pm 10$	$36 \pm 2 \pm 5$
W+jets	$6 \pm 1 \pm 2$	n/a	n/a
Z+jets	$0.5 \pm 0.3 \pm 0.3$	$11 \pm 4 \pm 3$	$3 \pm 1 \pm 1$
Fake leptons	$7 \pm 1 \pm 2$	$12 \pm 5 \pm 11$	$6 \pm 4 \pm 4$
Others	$0.3 \pm 0.1 \pm 0.1$	$2.7 \pm 0.9 \pm 0.7$	$0.9 \pm 0.2 \pm 0.5$
Total SM	$38 \pm 3 \pm 7$	$115 \pm 8 \pm 15$	$46 \pm 4 \pm 7$
Data	50	123	47
$m_{\tilde{t}_1} = 170\text{GeV}, m_{\tilde{\chi}_1^0} = 70\text{GeV}$	$26 \pm 2 \pm 6$	$57 \pm 3 \pm 6$	$36 \pm 2 \pm 4$
$m_{\tilde{t}_1} = 180\text{GeV}, m_{\tilde{\chi}_1^0} = 20\text{GeV}$	$20 \pm 2 \pm 4$	$41 \pm 3 \pm 5$	$27 \pm 2 \pm 3$
	95% CL upper limits		
σ_{vis} (expected) [fb]	4.2	9.3	4.6
σ_{vis} (observed) [fb]	6.1	11	5.2

Exclusion Limits





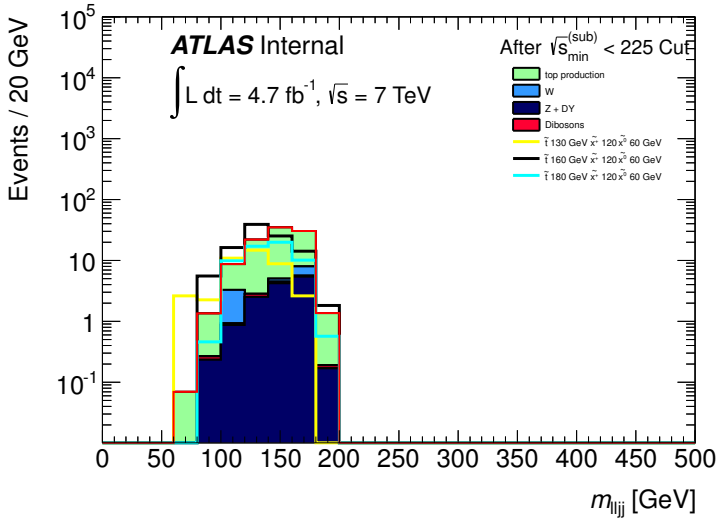
Conclusions

- Search for direct stop pair production for $m(\tilde{t}) \leq m(t)$
- Full 2011 dataset analyzed $(4.7\ fb^{-1})$
- No significant excess over SM prediction observed
- Exclusion limits set
  - ✓ $120 < m(\tilde{t}) < 190$ GeV depending on the neutralino mass excluded under gaugino universality assumption
  - ✓ $m(\tilde{t}) = m(t)$ excluded for $m(\tilde{\chi}_1^0) < 75$ GeV
  - ✓ $m(\tilde{t}) < 175$ GeV excluded for $m(\tilde{\chi}_1^0) = 60$ GeV and $m(\tilde{\chi}_1^{\pm}) = 106$ GeV
- Paper to be submitted to PLB at final stage of approval in ATLAS

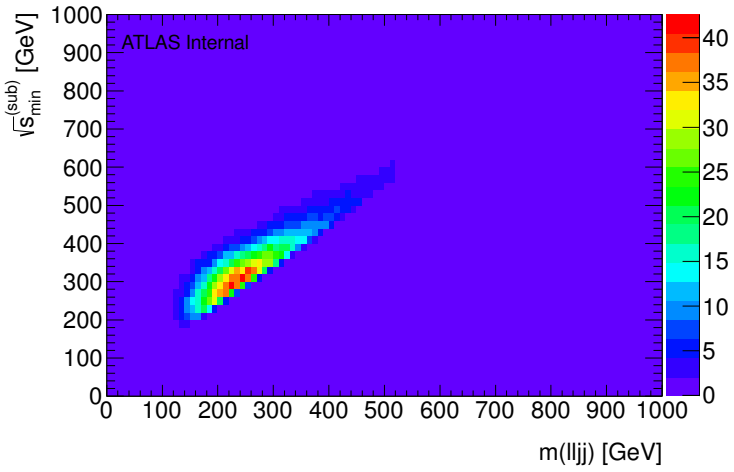
Backup

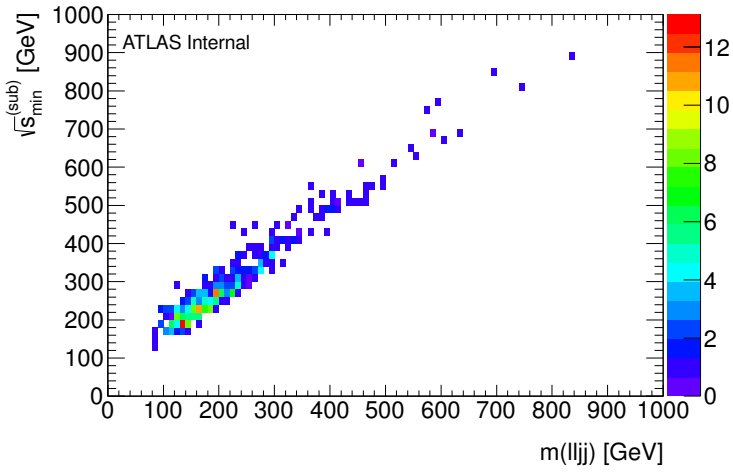
Choice of the SR

- Choice of $\sqrt{s}_{min}^{(sub)}$ cut based on best significance
- Sensitivity can be increased adding a $m(\ell\ell jj)$ upper cut



m(lljj) VS $\sqrt{s}_{min}^{(sub)}$ plots for $t\bar{t}$ (left) and signal sample $m(\tilde{t}) = 160$ GeV (right)





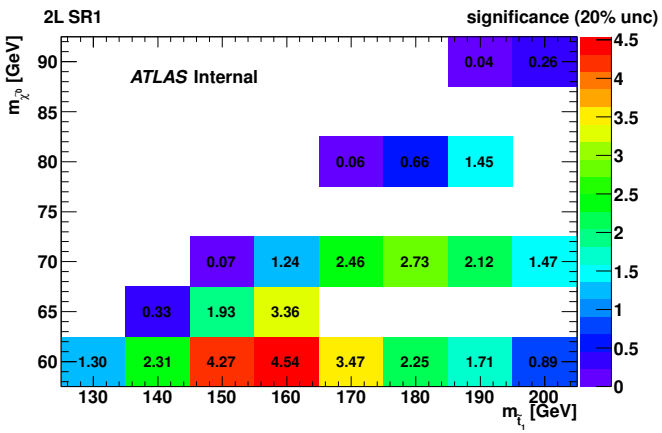
Choice of the SR (2)

$\longrightarrow$ Scan in $210-225$ GeV $\sqrt{s}_{min}^{(sub)}$ regions

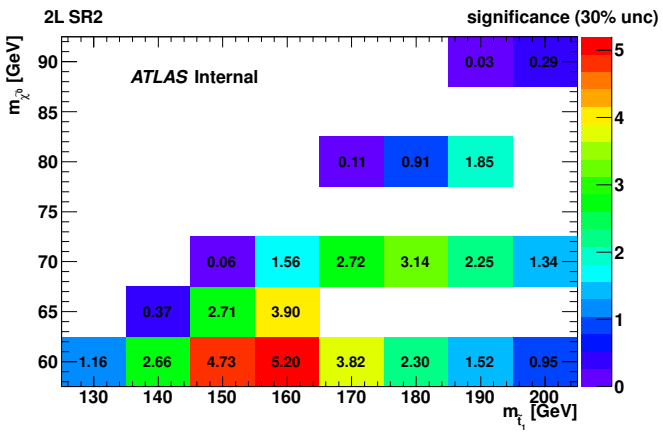
$\longrightarrow$ $\sqrt{s}_{min}^{(sub)} < 235$ and $m(\ell\ell jj) < 140$

Process	$\sqrt{s}_{min}^{(sub)}$ cut				$m(lljj)$ <140
	<225 GeV	<220 GeV	<215 GeV	<210 GeV	$\sqrt{s}_{min}^{(sub)}$ <235 GeV
$t\bar{t}$	74.1	55.6	41.9	31.5	29.0
single top	6.1	5.1	4.3	3.1	3.1
Z+HF	17.8	16.1	14.7	10.4	6.5
W+HF	5.3	5.3	5.3	2.9	2.4
Others	0.9	0.8	0.7	0.6	0.5
Total MC	104 ± 6	82 ± 9	67 ± 9	49 ± 6	42 ± 4

SR1: $\sqrt{s}_{min}^{(sub)} < 225$, unc. 20% Not in the note!



SR2: $\sqrt{s}_{min}^{(sub)} < 235$, $M < 140$, unc. 30% Not in the note!



Fakes Estimate

Fake-fake (QCD-multijets) and fake-real (W+jets, single top) contributions

$$\begin{pmatrix} N_{TT} \\ N_{Tl} \\ N_{lT} \\ N_{ll} \end{pmatrix} = M \begin{pmatrix} N_{LL}^{RR} \\ N_{LL}^{RF} \\ N_{LL}^{FR} \\ N_{LL}^{FF} \end{pmatrix}$$

- Tight leptons: pass object selection
- Loose leptonts: Fail isolation requirement

$$M = \begin{pmatrix} r_1 r_2 & r_1 f_2 & f_1 r_2 & f_1 f_2 \\ r_1(1-r_2) & r_1(1-f_2) & f_1(1-r_2) & f_1(1-f_2) \\ (1-r_1) r_2 & (1-r_1) f_2 & (1-f_1) r_2 & (1-f_1) f_2 \\ (1-r_1)(1-r_2) & (1-r_1)(1-f_2) & (1-f_1)(1-r_2) & (1-f_1)(1-f_2) \end{pmatrix}$$

fake f and real r rates from 2 leptons MT2 analysis ATLAS-COM-2012-022

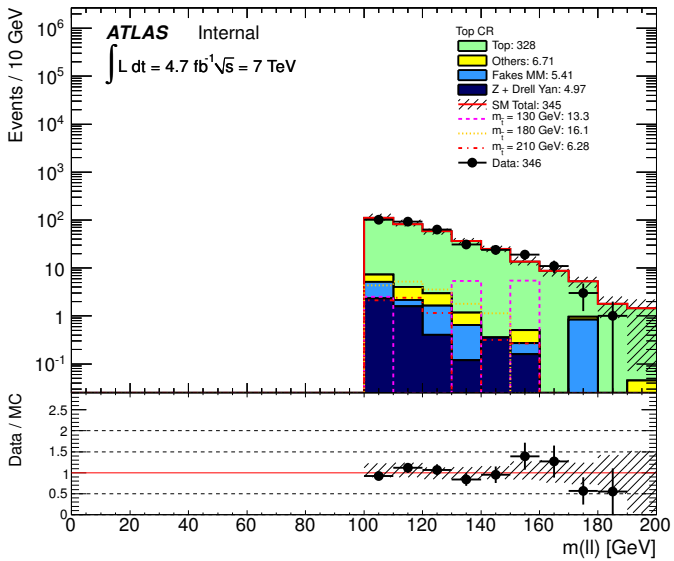
Fakes Estimate (2)

- Fake-fake contribution negligible
- Biggest contribution from fake-real: one real lepton, one jet misidentified
- Not real-real contribution removed from MC

DD results	ee	$\mu\mu$	$e\mu$	Total
Top CR; $m_{(ll)}$ >101 GeV, $\sqrt{s}_{min}^{(sub)} < 325$ GeV	3.3 ± 3.2	0.2 ± 1.6	1.9 ± 1.4	5.3 ± 5.1
Z CR; 81 $< m_{(ll)} <$101 GeV, $\sqrt{s}_{min}^{(sub)} < 225$ GeV	-0.1 ± 1.2	-0.2 ± 0.5	-	0.0 ± 1.3
SR1: $\sqrt{s}_{min}^{(sub)} < 225$ GeV	-0.3 ± 0.1	5.7 ± 2.8	6.4 ± 3.5	12.1 ± 4.9
SR2: $\sqrt{s}_{min}^{(sub)} < 235$ GeV + $m(lljj) < 140$ GeV	0.3 ± 1.5	3.6 ± 2.0	2.5 ± 2.5	6.4 ± 3.6
MC results	ee	$\mu\mu$	$e\mu$	Total
Top CR; $m_{(ll)}$ >101 GeV, $\sqrt{s}_{min}^{(sub)} < 325$ GeV	2.1 ± 0.2	0.8 ± 0.1	3.1 ± 0.6	5.9 ± 0.9
Z CR; 81 $< m_{(ll)} <$101 GeV, $\sqrt{s}_{min}^{(sub)} < 225$ GeV	0.2 ± 0.1	-0.0 ± 0.0	-	0.2 ± 0.1
SR1: $\sqrt{s}_{min}^{(sub)} < 225$ GeV	0.3 ± 0.1	2.4 ± 1.0	9.0 ± 6.7	11.8 ± 6.8
SR2: $\sqrt{s}_{min}^{(sub)} < 235$ GeV + $m(lljj) < 140$ GeV	0.1 ± 0.1	0.8 ± 0.5	7.4 ± 6.7	8.3 ± 6.7

$t\bar{t}$ and Wt Estimate

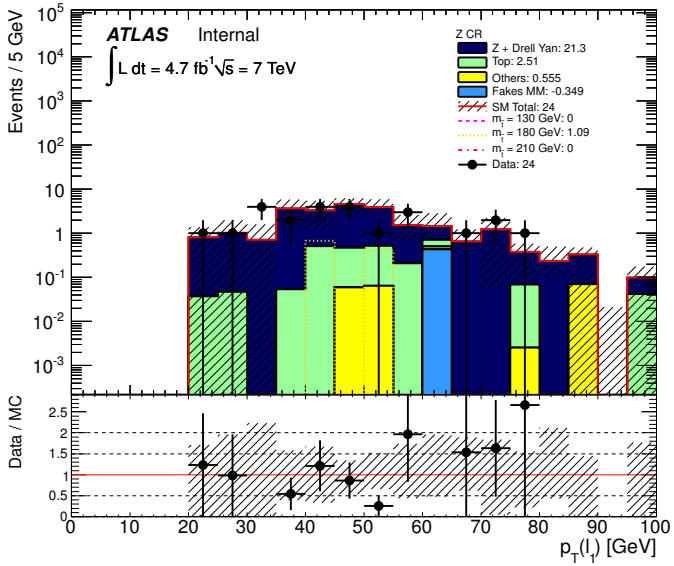
- ✓ Semi DD technique, top CR:
  - $m_{\ell\ell} > 101$ GeV
  - $\sqrt{s}_{min}^{(sub)} < 325$ GeV
- ✓ $w_{t\bar{t}} = 1.15 \pm 0.20$
  - $\rightarrow$ good agreement with 1lepton
- ✓ $TF_{top}^{SR1} = 0.27 \pm 0.03$
- ✓ $TF_{top}^{SR2} = 0.11 \pm 0.02$



Process	ee	$\mu\mu$	$e\mu$	Lepton Total
Top	58.0	79.2	142.7	280.0
Fakes	3.3	0.2	1.9	5.4
Z+jets	4.3	2.2	0	6.5
Others	1.5	1.8	3.3	6.7
Total SM	67.2 ± 11.3	83.4 ± 14.2	148.0 ± 20.9	298.5 ± 43.8
Data	75	97	174	346

Z Estimate

- ✓ Semi DD technique, Z CR:
  - $81 < m_{\ell\ell} < 101$ GeV
  - $\sqrt{s}_{min}^{(sub)} < 225$ GeV
  - Same flavor lepton
- ✓ $w_Z = 0.76 \pm 0.48$
- ✓ $TF_Z^{SR1} = 0.52 \pm 0.17$
- ✓ $TF_Z^{SR2} = 0.14 \pm 0.05$



Process	ee	$\mu\mu$	Lepton Total
Top	0.5	1.7	2.2
Fakes	0	0	0
Z+jets	9.5	18.1	27.6
Others	0.3	0.3	0.6
Total SM	10.3 ± 5.4	20.1 ± 7.6	30.4 ± 12.0
Data	8	16	24