5th Annual Workshop of the Helmholtz Alliance "Physics at the Terascale"

(Flavour Subtraction) di-lepton Analysis with ATLAS at $\sqrt{s} = 7$ TeV

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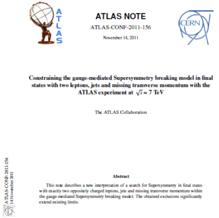
December 8^{th} 2011

Outline



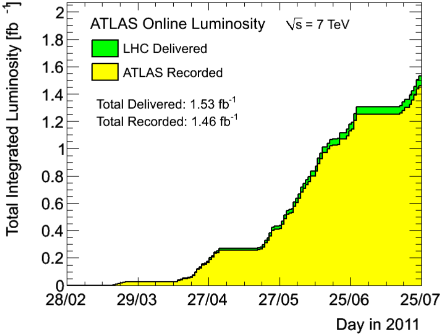
Search for SUSY with 2 leptons and E_T^{miss}
paper: ATLAS-SUSY-2011-10-001

Constraining the GMSB model with 2 leptons & E_T^{miss}
Conference note: ATLAS-CONF-2011-156

Data

Analysed data from period B-H

- total Luminosity after GRL
  $\int \mathcal{L}dt \sim 1.04\ fb^{-1}$
  - egamma stream
  - muon stream



period	runs	date	#runs	#events
B2	178109-178044	Wed Mar 23 - Thu Mar 24 2011	3	22299705
D	179710-180481	Fri Apr 15 - Thu Apr 28 2011	23	125652340
E	180614-180776	Sat Apr 30 - Tue May 03 2011	5	25772118
F	182013-182519	Sun May 15 - Wed May 25 2011	17	64483061
G	183462-182726	Sat May 28 - Tue Jun 14 2011	28	185703386
H	183544-184169	Thu Jun 16 - Tue Jun 28 2011	13	98041353
sum:	178109-184169	Wed Mar 23 - Tue Jun 28 2011	89	521951963

GRL:
data11_7TeV.periodAllYear_DetStatus-v18-pro08-05_CoolRunQuery-00-03-98_Susy.xml

Object Selection

Electrons

- ✓ Medium electrons
- ✓ $p_T > 20\ GeV$
  ($p_T > 25\ GeV$ if leading)
- ✓ $|\eta^{cl}| < 2.47$
- ✓ Removed if $\Delta R < 0.4$ with a jet
- ✓ electron quality (el_OQ & egammaPID::BADCLUSELECTRON) != 0
- ✓ Signal Electron:
  - tight and isolated $\left(\frac{p_T cone20}{p_T} < 0.1\right)$

Muons

- ✓ STACO recontructed combined or segment-tagged
- ✓ $p_T > 10\ GeV$
  ($p_T > 20\ GeV$ if leading)
- ✓ $|\eta| < 2.4$
- ✓ MCP track requiremets
- ✓ Removed if $\Delta R < 0.4$ with a jet
- ✓ Signal Muons:
  - Cosmic rejection :
    $|d_0| < 0.2mm \,\&\&\, |z_0| < 1.0mm$
  - isolated ($p_T cone20 < 1.8\ GeV$)

Missing E_T

- ✓ 'SimplifiedRefFinal'=
  Jet with $p_T > 20$GeV
  + signal leptons
  + TopoClusters not associated to objects
- ✓ Corrected for non-isolated muons

Jets

- ✓ AntiKt4Topo reconstructed
- ✓ $p_T > 20\ GeV$
- ✓ $|\eta| < 2.8$
- ✓ Removed if $\Delta R < 0.2$ with a selected electron

Trigger and Event Selection

Trigger

	Egamma	**Muons**
Data	*EF_e20_med*	*EF_mu*18
MC	*EF_e20_med*	reweighting tool

- ee: egamma stream & el trig
- $\mu\mu$: muon stream & μ trig
- eμ: combined egamma & muon stream

✓ egamma: el $p_T > 25$ GeV && el trig

✓ muon: μ $p_T > 20$ GeV && μ trig && (NO el trig || el $p_T < 25$ GeV)

Monte Carlo

- MC10b samples
- reweighted as function of $< \mu >$ to reproduce the pile up in data
- lepton efficiency scale factors applied

Trigger and Event Selection

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Preselection

- Jet cleaning cuts
- 'Simple' LAr hole veto for jets and electron
- Primary vtx at least 5 tracks
- veto in cosmic ray muons

Selection

- Exactly 2 leptons (e and μ)
- invariant mass of leptons: $M_{ll} > 12$ GeV
- Signal leptons tight and isolated

Signal Regions

Flavour Subtraction

- cancel **flavour symmetric** backgrounds (e.g. $t\bar{t}$) by subtraction: $\underbrace{(N_{e^\pm e^\mp} + N_{\mu^\pm \mu^\mp})}_{\text{same flavour}} - \underbrace{(N_{e^\pm \mu^\mp})}_{\text{opposite flavour}}$
- extra cuts needed to reduce **flavour asymmetric** bg like Z/γ^* and Dibosons

SR1 *soft* E_T^{MISS} and Z-mass veto

SR2 *soft* E_T^{MISS} and 2-jets

→ regions are complementary to cover complete $m_{\ell\ell}$ and SUSY with no jets

SR3 *tight* E_T^{MISS} (identical to OS-SR1)

→ inc. data-driven $t\bar{t}$ estimates

→ higher exclusion potential

Signal Region	FS-SR1	FS-SR2	FS-SR3
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	80	80	250
Number of jets	-	≥ 2	-
m_{ll} veto [GeV]	80-100	-	-

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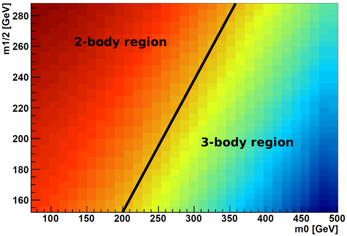
Opposite Sign

Optimization on mSUGRA GRID

- with: E_T^{MISS}, *jet multi.*, $p_T(jet)$
- for: $500pb^{-1}$

1. $m_{1/2} \gg m_0$ squark 2-body decay
2. $m_0 \gg m_{1/2}$ gluino 3-body decay

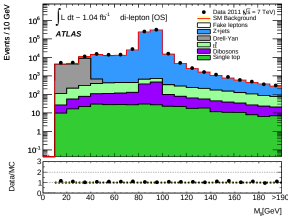


SR1 E_T^{MISS} cut only

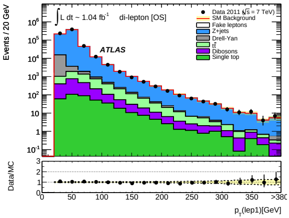
SR2 3-jets and E_T^{MISS} cuts (2-body)

SR3 4-jets and E_T^{MISS} cuts (3-body)

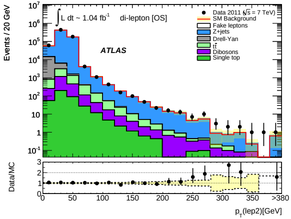
Kinematic Distributions



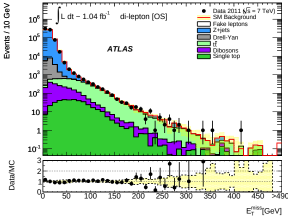
$m_{\ell\ell}$ [GeV]



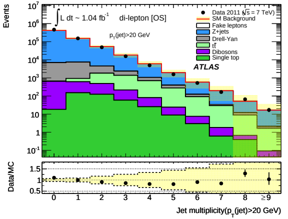
leading lepton $p_T >$ [GeV]



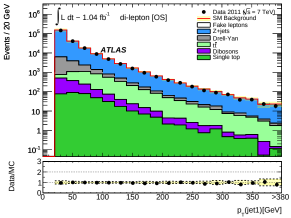
second lepton $p_T >$ [GeV]



$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]



N jets $p_T > 20$ GeV



leading jet p_T [GeV]

- overall good agreement between data and expected SM background
- 'Fake leptons' from data-driven estimation, other processes from Monte Carlo

Background Determination

Mixture of fully and partially data-driven techniques and MC-based estimates

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  - Data-driven: matrix method
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  - Semi data-driven method
    (estimates in SR from CR and transfer function from MC)
- $Z \rightarrow l^{\pm}l^{\mp}$ + jets (OS):
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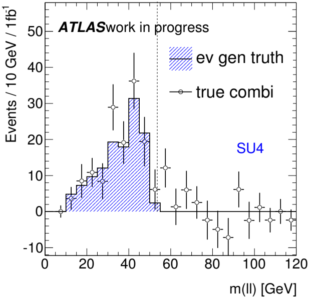
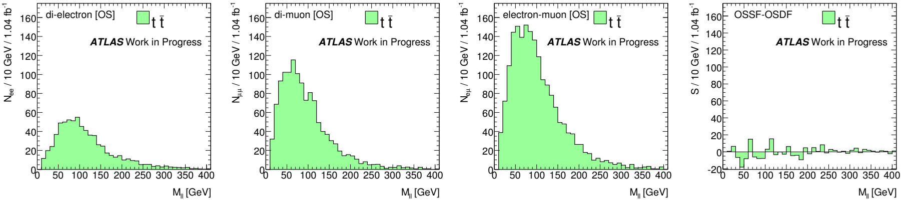
- Di-bosons (including WWjj)
- Single top:
  - both estimates based on Monte Carlo only (small contribution)

Motivation - Flavour Subtraction



- SUSY processes (di)-leptons:
  a) $\tilde{\chi}_i^0 \to l^\pm \nu \tilde{\chi}_j^\mp$
  b) $\tilde{\chi}_i^\pm \to l^\pm \nu \tilde{\chi}_j^0$
  c) $\tilde{\chi}_i^0 \to l^\pm l^\mp \tilde{\chi}_j^0$
  d) $\tilde{\chi}_i^\pm \to l^\pm l^\mp \tilde{\chi}_j^\pm$
  - FS is exclusively sensitive to same flavour excess

1. cleaning SUSY excess (c) from combinatorics (a,b) for $m_{\ell\ell}$ -edge fitting



2. reduction of flavour symmetric background (e.g.: $t\bar{t}$)

$$\mathcal{S} = a \cdot N_{e^\pm e^\mp} + b \cdot N_{\mu^\pm \mu^\mp} - c \cdot N_{e^\pm \mu^\mp}$$

3. reduction of correlated systematics (by subtraction)

FS-Analysis - Distributions

- $\mathcal{S}$ quantifies the excess of SF over DF events

$$\mathcal{S} = \underbrace{\frac{N(e^{\pm}e^{\mp})}{\beta(1-(1-\tau_e)^2)}}_{\text{SF}} - \underbrace{\frac{N(e^{\pm}\mu^{\mp})}{1-(1-\tau_e)(1-\tau_\mu)}}_{\text{DF}} + \underbrace{\frac{\beta N(\mu^{\pm}\mu^{\mp})}{(1-(1-\tau_\mu)^2)}}_{\text{SF}}$$

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- take into account
  - different trigger efficiencies (τ_e, τ_μ)
  - different lepton reco and ID efficiencies (ϵ_e, ϵ_μ) $\beta = \frac{\epsilon_e}{\epsilon_\mu}$
- τ_e, τ_μ and β measured in data:

β	τ_e	τ_μ
0.75 ± 0.05	0.964 ± 0.001	0.816 ± 0.003

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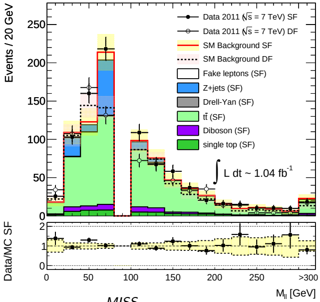
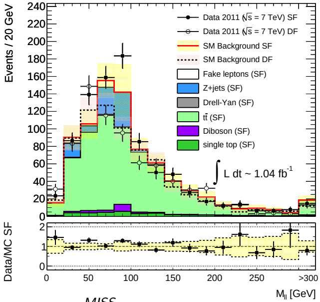
- plots show SF (ee and $\mu\mu$) and DF ($e\mu$) dist.
  - after correcting with β, τ_e, and τ_μ
  - • (yellow band): data (MC) for SF (ee and $\mu\mu$)
  - ○ (red band): data (MC) for DF ($e\mu$)
  - other colours: MC bg for SF distribution



FS-SR1: $E_T^{MISS} > 80$ GeV and Z-veto



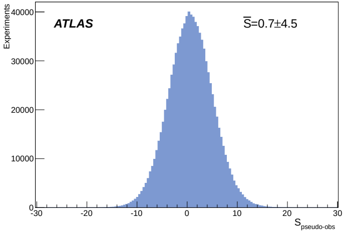
FS-SR2: $E_T^{MISS} > 80$ GeV and N jets >= 2

FS-Analysis - Limits

- Determine $\mathcal{S}$ with MC toy experiments:
  - toy experiment for each SM process ($t\bar{t}$,..) in each channel (ee, $e\mu$, $\mu\mu$)
  - nominal values based on data driven expectations
  - uncertainties considered as Gaussian distributions
- observed $\mathcal{S}_{obs}$ in agreement with SM pred.($\mathcal{S}_b$)

	$\mathcal{S}_{obs}$	$\bar{\mathcal{S}}_b$	RMS
FS-SR1	131.6±2.5(sys)	118.7±23.6±13.1	48.6
FS-SR2	142.2±1.0(sys)	67.1±23.2±16.7	49.0
FS-SR3	-3.1±0.0(4)(sys)	0.7±1.1±1.1	4.5

errors on $\bar{\mathcal{S}}_b$ are stat. and syst. errors



FS SR3

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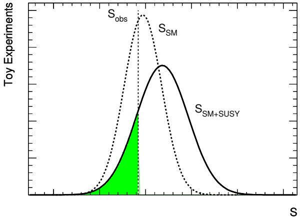


example of 95% exclusion

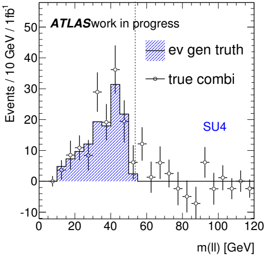
Limits:

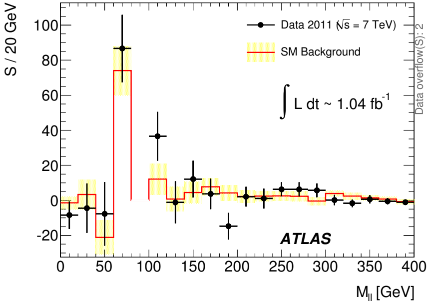
- Limit set on mean contribution of potential signal ($\bar{\mathcal{S}}_s$)
  - by adding *SUSY signal* to $\mathcal{S}_{SM+SUSY}$ until probability of $\mathcal{S}_{SM+SUSY} < \mathcal{S}_{obs}$ is smaller than 5% (green area)
- assumptions for signal events which are added to the toys as signal:
  - same BR for ee and $\mu\mu$ in SUSY events and NO contribution of eμ

	$\mathcal{S} > \mathcal{S}_{obs}$ (%)	Limit $\bar{\mathcal{S}}_s$ (95% CL)
FS-SR1	39	94
FS-SR2	6	158
FS-SR3	79	4.5

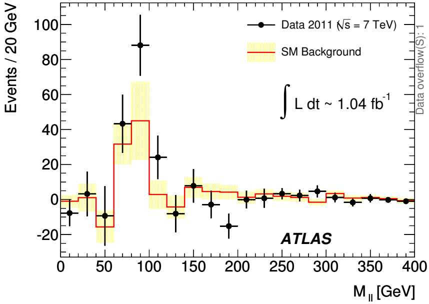
Flavour Subtraction - Outlook

- next step: considering shapes
- FS-SR1 and FS-SR2 with loose $E_{\mathrm{T}}^{\mathrm{miss}}$ -cut not yet taken into account for limits
- these SR have been developed for investigating shapes





(FS-SR1: $E_{\mathrm{T}}^{\mathrm{miss}} > 80$ GeV and Z-veto)



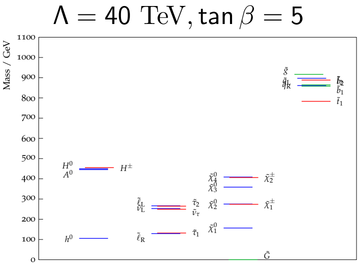
(FS-SR2: $E_{\mathrm{T}}^{\mathrm{miss}} > 80$ GeV and $nJets \geq 2$)

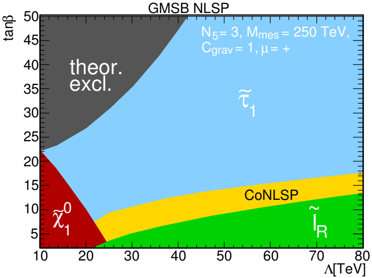
- ToDo: suppress Z more efficiently → (and) exploit $m_{\ell\ell}$ -shapes for limits

GMSB scenario

- **G**auge **M**ediated **S**ymmetry **B**reaking: Popular benchmark scenario studied already by LEP and Tevatron experiments
- Messenger fields at scale M_{mes} transmit breaking from the hidden to the accessible sector
- In total 6 parameters: Λ, M_{mes}, N_5, $\tan\beta$, sign(μ) and C_{grav}
- $\tilde{G}$ LSP (nearly massless)
- NLSP: $\tilde{\chi}_1^0$, $\tilde{\tau}_1$ or $\tilde{l}_R$
- $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G} \Longrightarrow$ **Diphoton** final states
- $\tilde{\chi}_1^0 \rightarrow \tilde{\tau}_1\tau \rightarrow \tau\tau\tilde{G} \Longrightarrow$ **tau** final states (But τ_{lep} decays!)
- $\tilde{\chi}_1^0 \rightarrow \tilde{l}_R l \rightarrow ll\tilde{G} \Longrightarrow$ **leptonic** final states

$\Rightarrow$ NLSP type drives decay topology!





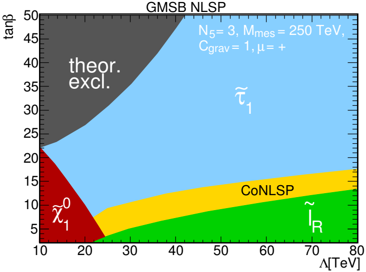
GMSB scenario: OS Dilepton analysis

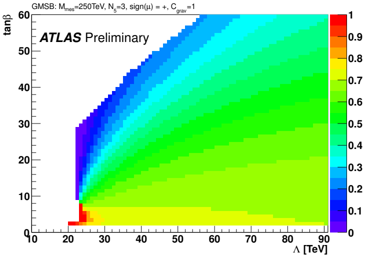
Dilepton Analysis on GMSB:

- Analysis requires **exactly** two leptons
- Lower sensitivity to $\tilde{\chi}_1^0$ NLSP region
- **OS** dilepton analysis targets $\tilde{\chi}_0 \rightarrow \tilde{l} + l \rightarrow l^+ l^- + \tilde{G}$ decays,
- In $\tilde{\tau}$ NLSP region, leptons via $\tilde{l} \rightarrow \tilde{\tau}\tau l$ 3-body decays
- Also covers τ_{lep} decays for $\tilde{\tau}$ NLSP region
- Cross sections drop rapidly with Λ

Signal Selection:

- **OS-SR2**: $\not{E}_T > 220$ GeV + 3 jets $> 80, 40, 40$ GeV

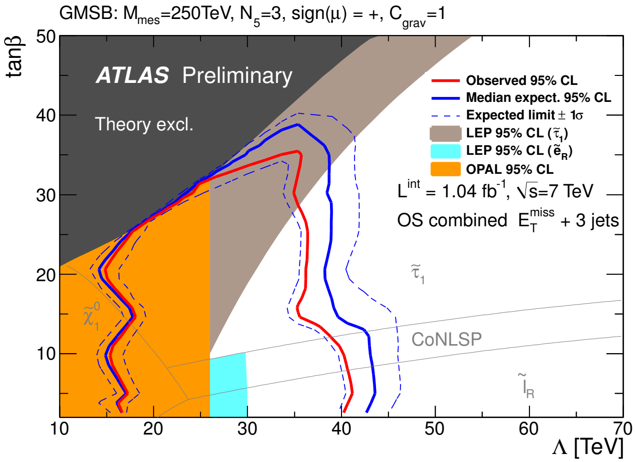




$\mathrm{BR}(\chi_1^0 \rightarrow \tilde{l}_R l)$

Limits: Combination of ee, $e\mu$, $\mu\mu$

- Profile likelihood method of constraining systematics
- Combination of CL_s limits for the individual channels



⇒ **World-best limit in this scenario!**

Conclusion

- Analysed first 1.04 fb^{-1} of ATLAS data from 2011 runs
- different 2-lepton + E_T^{MISS} analyses have been performed:
  - exclusive Flavour Subtraction (FS)
  - Opposite Sign(OS) new results in GMSB
- All SM backgrounds are evaluated
- Most relevant backgrounds are estimated from data or with semi-data driven techniques
  - Fake leptons, $t\bar{t}$, Z+jets
- FS: no FS excess observed → Limits set on one bin $\bar{\mathcal{S}}_s$
  - including shapes will be the next step...
- First limits on GMSB from dilepton analysis in ATLAS
  - World-best sensitivity in this scenario
- no new physics found so far...

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- First limits on GMSB from dilepton analysis in ATLAS
  - World-best sensitivity in this scenario

- no new physics found so far...

Conclusion

- Analysed first 1.04 fb^{-1} of ATLAS data from 2011 runs
- different 2-lepton + E_T^{MISS} analyses have been performed:
  - exclusive Flavour Subtraction (FS)
  - Opposite Sign(OS) new results in GMSB

- All SM backgrounds are evaluated
- Most relevant backgrounds are estimated from data or with semi-data driven techniques
  - Fake leptons, $t\bar{t}$, Z+jets

- FS: no FS excess observed → Limits set on one bin $\bar{\mathcal{S}}_s$
  - including shapes will be the next step...
- First limits on GMSB from dilepton analysis in ATLAS
  - World-best sensitivity in this scenario

- no new physics found so far...

Backup slides

Backgrounds Estimation Methods in Detail

Fake Backgrounds - method

Matrix Method

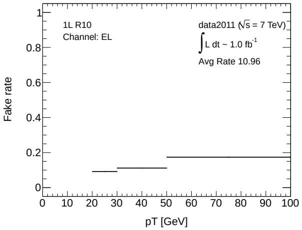
- loose leptons selection to have a QCD enriched sample
  - loose electrons: isEM medium, no isolation
  - loose muons: no isolation
- CRs to extract fake (QCD-CR) and real (Z-CR) efficiencies
- defined 1-lepton and 2-lepton same-sign QCD-CRs
  - μ fake rate from 2-lepton CR
  - e fake rate from 1-lepton CR
- p_T dependent fake rates are provided
- several CR have been analysed, following CR haven been chosen:

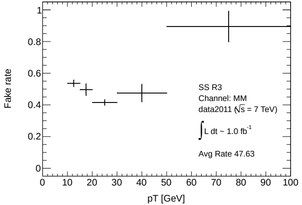
→ with best balance between purity and statistics

Electrons: R10 = $E_T^{MISS} < 30\ GeV$, $\Delta\phi_{E_T^{MISS},l} < 0.5$, $N_{jet} \geq 1$

Muons: R3 =$E_T^{MISS} < 30\ GeV$

	Efficiency	Fake rate		QCD CR
	Rate	Rate	Purity	
Electrons	86.15 ± 0.059	10.96 ± 0.02	94.94	R10
Muons	98.58 ± 0.015	47.63 ± 1.26	98.54	R3





QCD: The Matrix Method

The estimation of the fake background from QCD is done using the Matrix Method.

- for the fake rate estimation, looser samples of leptons, dominated by fakes, are obtained by relaxing the electron and muon identification criteria
  - *tight electrons and muons*: follow standard 2 lepton SUSY defintions
  - *loose electrons*: only required to pass isEM medium, no isolation cut
  - *loose muons*:no isolation cut

$$\begin{bmatrix} N_{TT} \\ N_{TL} \\ N_{LT} \\ N_{LL} \end{bmatrix} = \begin{bmatrix} rr & rf & fr & ff \\ r(1-r) & r(1-f) & f(1-r) & f(1-f) \\ (1-r)r & (1-r)f & (1-f)r & (1-f)f \\ (1-r)(1-r) & (1-r)(1-f) & (1-f)(1-r) & (1-f)(1-f) \end{bmatrix} \begin{bmatrix} N_{RR} \\ N_{RF} \\ N_{FR} \\ N_{FF} \end{bmatrix}$$

- N_{TT}, N_{TL}, N_{LT} N_{LL} are extracted from data
- r and f estimated from proper control regions and using the loose and tight selection of leptons
- by inverting the matrix we get the estimated number of N_{RR}, N_{RF}, N_{FR} and N_{FF}

$Z/\gamma \rightarrow ll$+jets

Semi data driven estimate:

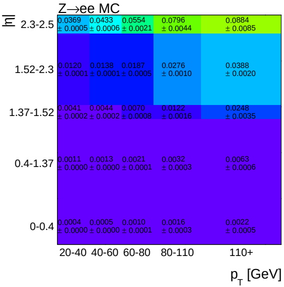
$$N^{est,SR}_{Z/\gamma^*} = \beta \cdot N^{data,CR}_{Z/\gamma^*} \qquad \text{with } \beta_{CR \rightarrow SR} = \frac{N^{MC,SR}_{Z/\gamma^*}}{N^{MC,CR}_{Z/\gamma^*}}$$

- $N^{data,CR}_{Z/\gamma^*} = (N^{data,CR} - N^{MC,CR}_{non-Z/\gamma^*})$
  - → events with $81 < m_{ll} < 101\ GeV$, $E_T^{MISS} < 20\ GeV$
  - → corrected for the other backgrounds contamination
- SR: any of the SUSY 2l SRs (SR1, SR2, SR3)
- CR: signal leptons cut + ($E_T^{MISS} < 20\ GeV$ and $81 < m_{ll} < 101\ GeV$)
  - → OS-CR1: all jet multiplicities
  - → OS-CR2: 3 jets (p_T >80, 40, 40 GeV)
  - → OS-CR3: 4 jets (p_T >100, 70, 70, 70 GeV)

	OS SR1	OS SR2	OS SR3
	ee		
β	$7.57 \times 10^{-8} \pm 4.3 \times 10^{-8}$(stat.)	0.002 ± 0.001(stat.)	0.004 ± 0.004(stat.)
$N^{est,SR}_{Z/\gamma^*}$	0.013 ± 0.672(sys.) ± 0.008(stat.)	0.45 ± 0.44(sys.) ± 0.23(stat.)	0.01 ± 0.17(sys.) ± 0.01(stat.)
$N^{MC,SR}_{Z/\gamma^*}$	0.012 ± 0.007(stat.)	0.43 ± 0.22(stat.)	0.01 ± 0.01(stat.)
	$\mu\mu$		
β	$2.62 \times 10^{-6} \pm 0.83 \times 10^{-6}$(stat.)	0.001 ± 0.000(stat.)	0.054 ± 0.033(stat.)
$N^{est,SR}_{Z/\gamma^*}$	0.81 ± 0.06(sys.) ± 0.26(stat.)	0.27 ± 0.27(sys.) ± 0.14(stat.)	0.27 ± 0.47(sys.) ± 0.20(stat.)
$N^{MC,SR}_{Z/\gamma^*}$	0.745 ± 0.236(stat.)	0.29 ± 0.14(stat.)	0.38 ± 0.22(stat.)
	$e\mu$		
$N^{MC,SR}_{Z/\gamma^*}$	1.028 ± 0.420(stat.)	0.84 ± 0.59(stat.)	0.00 ± 0.00(stat.)

Charge Mis ID of $t\bar{t}$ background in same sign analysis

- charge flip:
  $(e^{\mp}_{hard} \rightarrow \gamma_{hard}\, e^{\mp}_{soft} \rightarrow e^{\mp}_{soft}\, e^{\mp}_{soft}\, e^{\pm}_{hard})$
- background in $e^{\pm}e^{\pm}$ and $e^{\pm}\mu^{\pm}$ channels
- charge flip rate estimated in MC with $Z \rightarrow ee$ and $t\bar{t}$ samples



$$k = \overline{FR}_{data}/\overline{FR}_{MC} = 0.813 \pm 0.026$$
$$SS_{estimate} = MC_{SF}(OS) \cdot flipRate \cdot k$$

- using a Z enriched control samples for a closure test

→ in Z CR SS: MC: 1768 ± 17(stat) ± 27(syst) agreement with data: 1768 ± 42

- estimates of dilepton $t\bar{t}$ background in $e^{\pm}e^{\pm}$ and $e^{\pm}\mu^{\pm}$ channels
  - taking into account corrections to avoid double count with matrix fake estimation

	$e^{\pm}e^{\pm}$			$e^{\pm}\mu^{\pm}$		
SR1	0.73	±0.06 (syst)	±0.05 (stat)	1.10	±0.08 (syst)	±0.07 (stat)
SR2	0.59	±0.04 (syst)	±0.04 (stat)	1.36	±0.06 (syst)	±0.05 (stat)

Top Estimation

Two methods for the estimate available for cross checks
(MCT-tagger and kinematic top tagger)

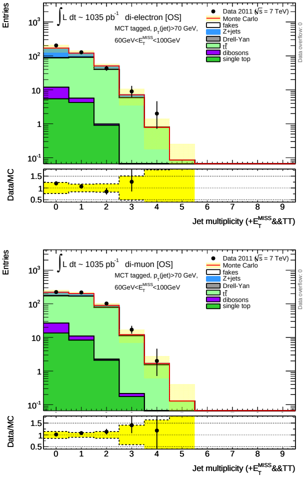
- exploit top dilepton decay kinematics to tag $t\bar{t}$ like events in intermediate E_T^{MISS} region
- define CRs that are similar to corresponding SR (to reduce systematic uncertainties)
- extrapolate from CR to SR

- The number of $t\bar{t}$ events in the signal region $(N_{tt})_{SR}$ is given by:

$$(N_{tt})_{SR} = \left((N_{data}^{tag})_{CR} - (N_{non-tt,MC}^{tag})_{CR}\right) f_{CR\rightarrow SR}$$

- with the extrapolation factor given by

$$f_{CR\rightarrow SR} = \frac{(N_{top,MC})_{SR}}{(N_{top,MC}^{tag})_{CR}}$$



performance of the MCT-tagger for p_T(jet)>70 GeV and 60 GeV$< E_T^{MISS} <$ 100 GeV

MCT-Tagger: Results

- Observed event counts and expected sample composition of the CR:

Control region	CR1	CR2	CR3
data	1010	238	52
$t\bar{t}$	848.3	227.2	41.2
Wt	48.2	4.1	0.8
Z / γ + jets	66.0	18.7	5.4
diboson	22.2	0.5	0.1
fakes	39	13	5
Total expected	1023.7	263.6	52.5
Total non-$t\bar{t}$	175.4	36.4	11.2

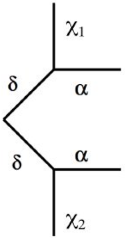
- Estimated top background in the three opposite sign signal regions:

Signal region	ee	$\mu\mu$	eμ
SR1	1.84 ± 0.07 ± 0.26 ± 0.42	3.34 ± 0.13 ± 0.47 ± 0.74	5.09 ± 0.19 ± 0.72 ± 1.14
SR2	1.41 ± 0.11 ± 0.21 ± 0.26	2.56 ± 0.20 ± 0.39 ± 0.48	3.90 ± 0.30 ± 0.59 ± 0.74
SR3	0.77 ± 0.14 ± 0.16 ± 0.48	1.40 ± 0.25 ± 0.29 ± 0.87	2.14 ± 0.38 ± 0.44 ± 1.34

uncertainties: (stat.) (uncorr. syst.) (corr syst.)

- The uncertainty is broken into:
  - statistical (either from MC or the observed rate in the control region)
  - correlated systematics (from JES and JER)
  - uncorrelated systematics (all the other sources, dominated by the ISR/FSR and generator uncertainties)

$t\bar{t}$ Background (OS): Contransverse Mass Tagger



- In the decay of a two pair-produced heavy states δ which decay via $\delta \rightarrow \alpha\chi_i$:
$$m^2_{CT}(\chi_1, \chi_2) = [E_T(\chi_1) + E_T(\chi_2)]^2 - [\mathbf{p_T}(\chi_1) - \mathbf{p_T}(\chi_2)]^2$$
- m_{CT} distributions have endpoints defined by $m(\delta)$, $m(\alpha)$ and the vector sum of transverse momenta of the visible particles upstream of the system for which the contransverse mass is calculated (p_b)
- For the $t\bar{t}$ system $m_{CT}(\ell\ell)$, $m_{CT}(jj)$, $m_{CT}(j\ell, j\ell)$ can be constructed

Contransverse mass tagger

1. Event with least 2 jets with $p_T > 20$ GeV
2. Consider all 2 jet permutations j_1, j_2, such that the two jets have $p_T > 20$ GeV and $p_T(j_1) + p_T(j_2) + p_T(\ell_1) + p_T(\ell_2) > 100$ GeV
3. $m_{CT}(\ell_1, \ell_2)$ in the allowed area of the $(m_{CT}(\ell_1, \ell_2), p_b(\ell\ell))$ plane
4. Build all pairs $((j_i\ell_1)(j_j\ell)_2)$ such that $m(j_i\ell_1) < 155$ GeV and $m(j_j\ell_2) < 155$ GeV
5. One combination with $m_{CT}(jj)$ in the allowed area of the $m_{CT}(jj)$, $p_b(jj)$ plane
6. $m_{CT}(j\ell, j\ell)$ should be compatible with $t\bar{t}$

- m_{CT} tagger has an efficiency of 85% in signal region
- Control region for $t\bar{t}$ estimation:
  - m_{CT}-tagged events
  - $60 < E_T^{miss} < 80$ GeV

Kinematic Top Tagger: Method

Kinematic Top Tagger:

- full kinematic reconstruction of dilepton events
- Solve a 6 equation system
- an event is top tagged as dilepton event if it has 2 signal leptons and at least 1 kinematic solution based on the 2 leading jets

A $t\bar{t}$event with the decay $t\bar{t} \rightarrow (W^+b)(W^-\bar{b}) \rightarrow (\ell^+\nu_\ell b)(\ell^-\bar{\nu}_\ell\bar{b})$ must fulfill the following kinematic equation system:

$$(p_\nu + p_{\ell^+})^2 = m_W^2 \quad (13)$$
$$(p_{\bar{\nu}} + p_{\ell^-})^2 = m_W^2 \quad (14)$$
$$(p_\nu + p_{\ell^+} + p_b)^2 = m_t^2 \quad (15)$$
$$(p_{\bar{\nu}} + p_{\ell^-} + p_{\bar{b}})^2 = m_t^2 \quad (16)$$
$$p_{\nu_x} + p_{\bar{\nu}_x} = E_{\mathrm{T},x}^{\mathrm{miss}} \quad (17)$$
$$p_{\nu_y} + p_{\bar{\nu}_y} = E_{\mathrm{T},y}^{\mathrm{miss}} \quad (18)$$
$$(19)$$

Kinematic Top Tagger: Results

Several control regions investigated, best expected performance with:

Control Region	Definition
E2	$E_T^{MISS} > 60$ GeV, 2 jets ($p_T > 40, 40$ GeV) and top-tag
E4	$E_T^{MISS} > 60$ GeV, 3 jets ($p_T > 40, 40, 40$ GeV) and top-tag
..	

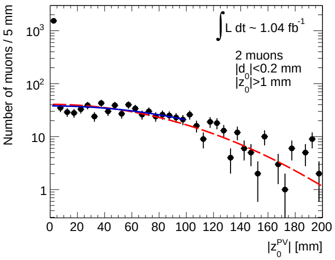
Estimates in signal regions:

Channel	$f_{CR \to SR}$	Predicted non-$t\bar{t}$	Observed yield in Control Region	Predicted $t\bar{t}$ Signal Region
OS-SR1 with Control Region E2				
ee	0.0262± 0.0013	13.46	108	2.48 ± 0.74 (sys) ± 0.24 (sta)
$\mu\mu$	0.0194± 0.0007	23.45	276	4.91 ± 1.45 (sys) ± 0.30 (sta)
$e\mu$	0.0220± 0.0007	11.99	324	6.86 ± 2.02 (sys) ± 0.38 (sta)
OS-SR2 with Control Region E4				
ee	0.1001± 0.0054	1.94	25	2.31 ± 0.42 (sys) ± 0.46 (sta)
$\mu\mu$	0.0746± 0.0032	3.10	62	4.40 ± 0.79 (sys) ± 0.56 (sta)
$e\mu$	0.0802± 0.0026	2.25	76	5.92 ± 1.05 (sys) ± 0.68 (sta)
OS-SR3 with Control Region E4				
ee	0.0526± 0.0040	1.94	25	1.21 ± 1.23 (sys) ± 0.24 (sta)
$\mu\mu$	0.0461± 0.0025	3.10	62	2.71 ± 2.74 (sys) ± 0.34 (sta)
$e\mu$	0.0488± 0.0020	2.25	76	3.60 ± 3.64 (sys) ± 0.41 (sta)

Cosmic Contamination

- default control region:
  $5 < |z_0^{\mathrm{PV}}| < 100$ mm
- two methods: extrapolation to SR with ratio of areas or fits

→ estimation: $6.1 \pm 1.4(\mathrm{stat}) \pm 1.3(\mathrm{syst})$ cosmics at $|z_0^{\mathrm{PV}}| < 1$ mm.



- considering additional cuts like $E_T^{MISS} > 250$ GeV for OS and $E_T^{MISS} > 100$ GeV for SS in muon CR

→ no muons are observed in the cosmics-enriched sample

→ upper limit on $(N_{\mathrm{muons}}^{\mathrm{CR}}) < 1.32$ with 68% C.L.

- extrapolate to SR: $N_{\mathrm{cosmics}}^{\mathrm{SR}} < 1.32 \times 1/95 = 0.014$ (conservative)

- Gaussian fit gives: $\lesssim 10^{-3}$ cosmic muons at $|z_0^{\mathrm{PV}}| < 1$ mm with $E_T^{MISS} > 100$ GeV for either SS or OS analyses before any jet cut
- conservative estimate of the contribution in the $e\mu$ channels of $\leq 10^{-3}$

Analysis Overview
ATLAS-SUSY-2011-10-001

Analysis Overview

As in 2010 3 analyses are performed:

SS Same Sign:

- production of SS-squarks or gluinos
  → single lepton per leg (decays a and b)
- very small Standard Model background,
  - main backgrounds: fakes, dibosons, events with charge misidentification

a) $\tilde{\chi}_i^0 \rightarrow l^{\pm}\nu\tilde{\chi}_j^{\mp}$

b) $\tilde{\chi}_i^{\pm} \rightarrow l^{\pm}\nu\tilde{\chi}_j^{0}$

c) $\tilde{\chi}_i^0 \rightarrow l^{\pm}l^{\mp}\tilde{\chi}_j^{0}$

d) $\tilde{\chi}_i^{\pm} \rightarrow l^{\pm}l^{\mp}\tilde{\chi}_j^{\pm}$

OS Opposite Sign:

- all the decay chains can contribute to the OS rate
- bigger Standard Model background, main background: $t\bar{t}$

FS Flavour Subtraction:

- exclusive analysis sensitive to SUSY decays that produce identical flavour lepton pairs (decays c and d)
- exploits cancellation of SM flavour-symmetric processes (e.g. $t\bar{t}$)
- Only flavour asymmetric backgrounds (Z and di-bosons) remain

→ all analyses share same Event Selection and Object Definition

Cutflow and Limits: OS- and SS-Analysis

- no excess observed - data agrees with background estimations
- channel (ee, eμ and $\mu\mu$) are analysed seperately and combined
- setting limit on A$\times\epsilon\times\sigma$ for each opposite-sign and same-sign
- limits obtained using CL_s prescription

Signal Region	Channel	Predicted Background	Observation
OS-SR1	ee	2.67 ± 1.34 (tot.)	2
OS-SR1	$\mu\mu$	5.30 ± 1.37 (tot.)	3
OS-SR1	eμ	7.55 ± 2.20 (tot.)	8
OS-SR2	ee	1.92 ± 0.84 (tot.)	3
OS-SR2	$\mu\mu$	3.16 ± 1.03 (tot.)	5
OS-SR2	eμ	7.93 ± 3.12 (tot.)	9
OS-SR3	ee	0.91 ± 0.99 (tot.)	0
OS-SR3	$\mu\mu$	1.77 ± 1.19 (tot.)	1
OS-SR3	eμ	3.05 ± 1.75 (tot.)	1
SS-SR1	ee	5.01 ± 2.15 (tot.)	6
SS-SR1	$\mu\mu$	10.31 ± 3.47 (tot.)	5
SS-SR1	eμ	17.23 ± 3.22 (tot.)	14
SS-SR2	ee	2.38 ± 2.06 (tot.)	4
SS-SR2	$\mu\mu$	6.91 ± 3.08 (tot.)	10
SS-SR2	eμ	15.62 ± 4.23 (tot.)	14

Cutflow and Limits: OS- and SS-Analysis

- no excess observed - data agrees with background estimations
- channel (ee, eμ and $\mu\mu$) are analysed seperately and combined
- setting limit on A$\times\epsilon\times\sigma$ for each opposite-sign and same-sign
- limits obtained using CL$_s$ prescription

Signal Region	Channel	Predicted Background	Observation
OS-SR1	ee	2.67 $\pm$ 1.34 (tot.)	2
OS-SR1	$\mu\mu$	5.30 $\pm$ 1.37 (tot.)	3
OS-SR1	eμ	7.55 $\pm$ 2.20 (tot.)	8
OS-SR2	ee	1.92 $\pm$ 0.84 (tot.)	3
OS-SR2	$\mu\mu$	3.16 $\pm$ 1.03 (tot.)	5

	Background	Obs.	95% CL
OS-SR1	15.5 $\pm$ 1.2 $\pm$ 3.8	13	9.9 fb
OS-SR2	13.0 $\pm$ 1.8 $\pm$ 3.6	17	14.4 fb
OS-SR3	5.7 $\pm$ 1.1 $\pm$ 3.4	2	6.4 fb
SS-SR1	32.6 $\pm$ 4.4 $\pm$ 6.0	25	14.8 fb
SS-SR2	24.9 $\pm$ 4.1 $\pm$ 4.2	28	17.7 fb

stat. and syst. errors

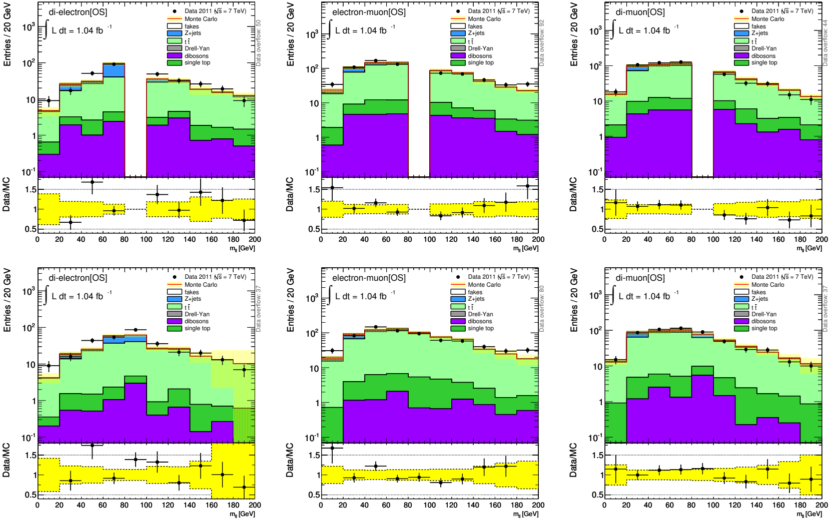
Flavour Subtraction

Cutflow of FS signal regions

OS-FS [FS-SR1]	$e^{\pm}e^{\mp}$	$e^{\pm}\mu^{\mp}$	$\mu^{\pm}\mu^{\mp}$
$t\bar{t}$	198±8±19	581±14±48	418±11±29
Z/γ^*+jets	86±5±5	41±3±6	41±3±11
Fakes	5±2±2	30±6±6	22±6±5
Dibosons	14±2±2	34±3±4	32±2±3
single top	13±1±1	41±2±3	37±2±2
Standard Model	316±10±19	727±16±49	549±14±31
Cosmic rays	$< 10^{-3}$	$< 10^{-3}$	$< 10^{-3}$
Observed	344	750	551
OS-FS [FS-SR2]	$e^{\pm}e^{\mp}$	$e^{\pm}\mu^{\mp}$	$\mu^{\pm}\mu^{\mp}$
$t\bar{t}$	220±9±23	624±15±62	437±12±35
Z/γ^*+jets	46±3±12	29±3±6	38±3±5
Fakes	2±2±1	32±6±8	19±6±6
Dibosons	8±1±3	11±2±5	15±1±5
single top	10±1±2	32±2±4	27±1±3
Standard Model	286±10±26	728±16±63	537±13±36
Cosmic rays	$< 10^{-3}$	$< 10^{-3}$	$< 10^{-3}$
Observed	336	741	567
OS-FS [FS-SR3]	$e^{\pm}e^{\mp}$	$e^{\pm}\mu^{\mp}$	$\mu^{\pm}\mu^{\mp}$
$t\bar{t}$	1.8±0.1±0.5	5.1±0.2±1.4	3.3±0.1±0.9
Z/γ^*+jets	0.01±0.01±0.67	1.03±0.42±0.02	0.81±0.26±0.06
Fakes	0.17±0.19±0.08	0.92±0.96±0.17	-0.08±0.03±0.01
Dibosons	0.54±0.29±0.07	0.04±0.03±0.03	0.67±0.25±0.31
Single-top	0.11±0.11±0.05	0.47±0.16±0.16	0.48±0.17±0.09
Standard Model	2.7±0.4±1.2	7.6±1.1±1.5	5.3±0.4±1.3
Cosmic rays	$< 10^{-3}$	$< 10^{-3}$	$< 10^{-3}$
Observed	2	8	3

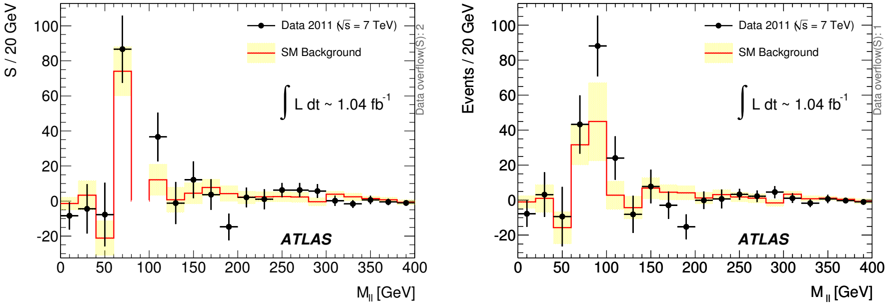
- biggest contribution $t\bar{t}$ will be suppressed in the flavour subtraction step
- Standard Model Monte Carlo in good agreement with data
- no same flavour excess observed → can be transformed in exclusions

FS Data and Monte Carlo distributions for diff. channels



- Data and Monte Carlo distributions for the three channels OS ee, eμ and $\mu\mu$ channels respectively in FS-SR1 (upper row) and FS-SR2 (lower row)

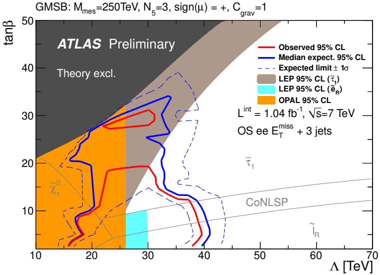
Data and Monte Carlo distributions after flavour subtraction

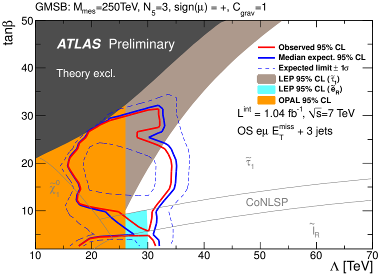


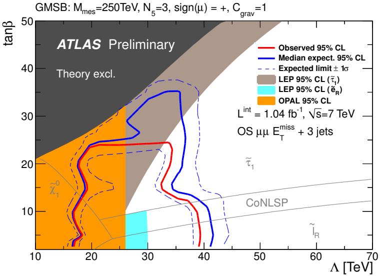
- Data and Monte Carlo distributions after flavour subtraction for signal regions FS-SR1 (left) FS-SR2 (right)

GMSB Interpretation

Limits: Individual channels







- Transition due to the BR change
- Soft leptons for $\tilde{\tau}_1$ NLSP points (leptonic τ decays)