Estimation of SM backgrounds to SUSY search in the 1-lepton+jets+E_T^{miss} channel

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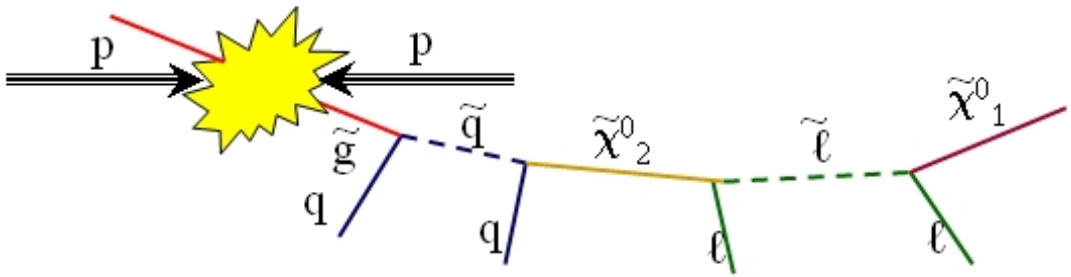
Typical SUSY signature



- gluinos and squarks from quark/gluon interaction
- decay into jets, leptons and LSP (= **L**ightest **S**upersymmetric **P**article)
- LSP escapes detector (LSP is neutral, weakly interacting and stable in R-parity conserving models)
  $\Rightarrow$ Missing Transverse Energy (E_T^{miss})
- Typical SUSY signature: jets + leptons + E_T^{miss}

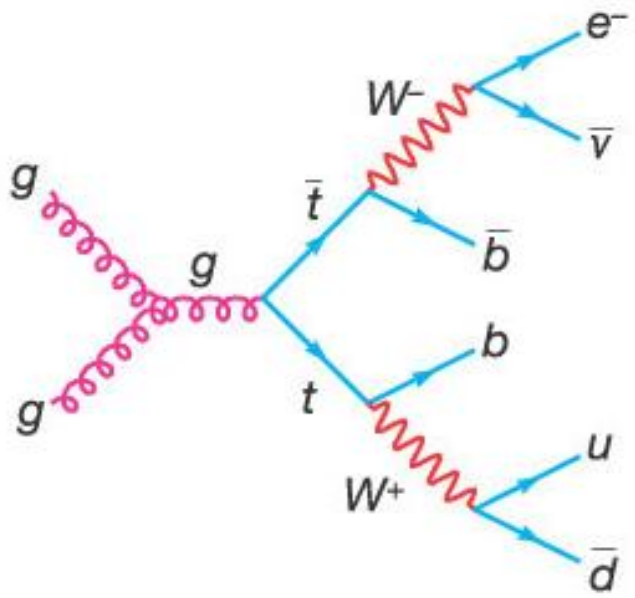
Main backgrounds in the 1-lepton channel

A typical SM background event has multiple jets, a (fake) lepton and E_T^{miss}

- $t\bar{t}$ pairs with semi-leptonic or fully-leptonic decay topology

  Most important background in 1-lepton channel
- W+jets with lepton from $W \to l\nu$
- QCD

  (heavy flavor decays, conversions, hadrons, jets misidentified as an isolated lepton)



SUSY selection cuts in 1-lepton + 3 jets channel

Definition of the channel

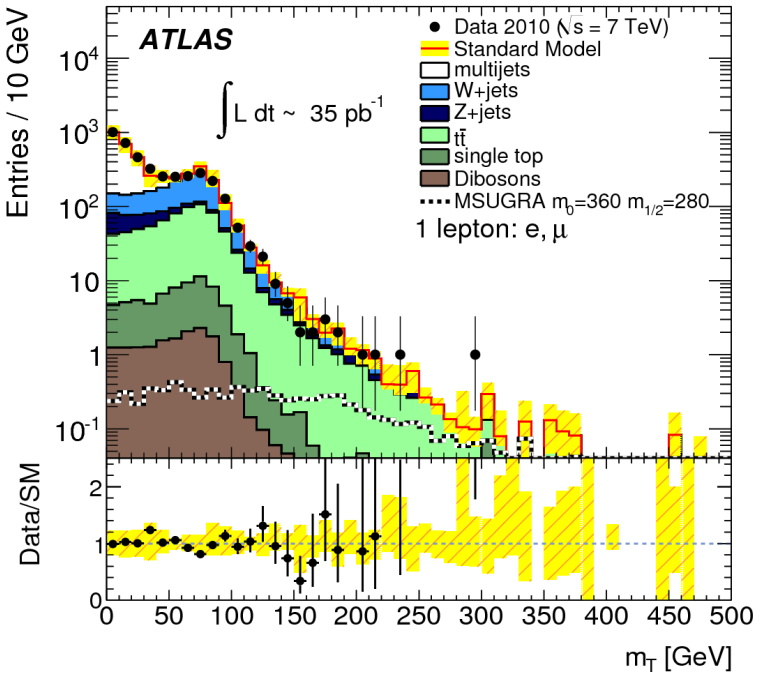
1. One isolated lepton with $p_T > 20\ GeV$
2. 3 jets with $p_T^{leading\ jet} > 60\ GeV$, $p_T^{third\ jet} > 30\ GeV$

Background reduction

3. $\Delta\phi(jet, E_T^{miss}) > 0.2$
4. $E_T^{miss} > 125\ GeV$
5. $M_T > 100\ GeV$ with
   $M_T = \sqrt{2 \cdot p_T^l \cdot E_T^{miss} \cdot (1 - \cos(\Delta\phi(l, E_T^{miss})))}$
6. $E_T^{miss} > 0.25 M_{eff}$ with $M_{eff} = p_T^l + E_T^{miss} + \sum p_T^{jet}$

SUSY mass scale

7. $M_{eff} > 500\ GeV$



M_T distribution after lepton and jet cuts

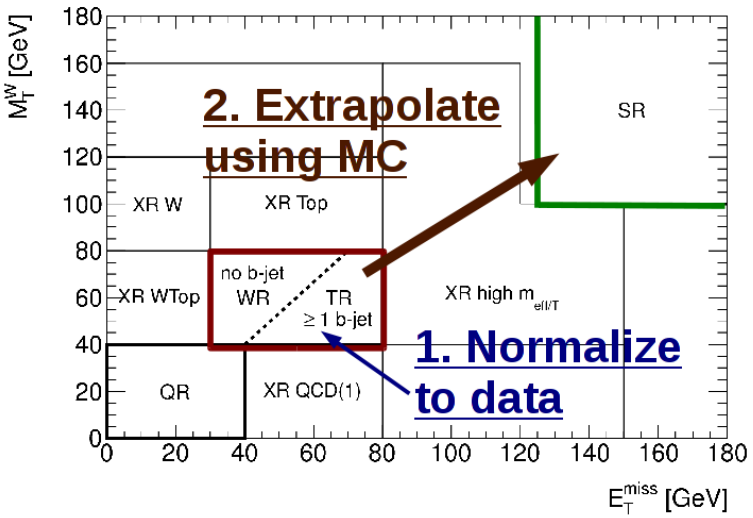
- W+jets BG is smaller than $t\bar{t}$ BG because of M_T cut
- QCD BG small by construction of SUSY signal selection cuts

Top and W+jets background

Estimate the background in the SUSY signal region with the help of background dominated control regions

Definition of W and top control region

- Lepton cuts and jet cuts, $\Delta\phi(jet, E_T^{miss}) > 0.2$ as in SUSY signal selection cuts
- $30\ GeV < E_T^{miss} < 80\ GeV$, $40\ GeV < M_T < 80\ GeV$
- Separate top background from W background:
  - Top background: ≥ 1 b-jet in three leading jets (T R)
  - W background: No b-jet (W R)

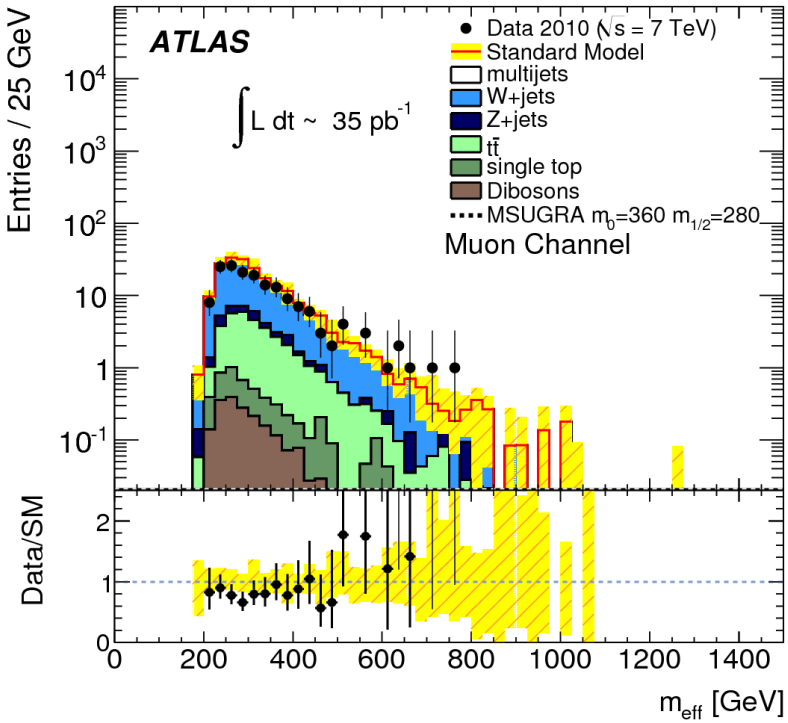


Top or W BG is measured in control region and extrapolated to signal region - for example top BG:

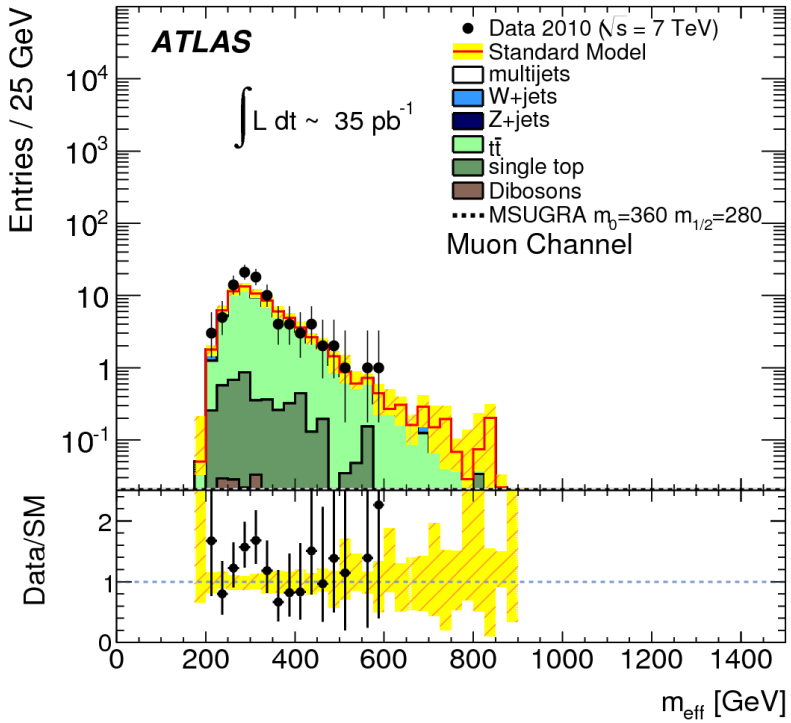
$$\underbrace{N(t\bar{t}\ pred.,\ SR)}_{\text{predicted events in signal region}} = \underbrace{(N(fitted\ t\bar{t}(data),\ CR))}_{\text{measured events in control region - other BG}} \times \underbrace{\frac{N(t\bar{t}(MC),\ SR)}{N(t\bar{t}(MC),\ CR)}}_{\text{extrapolation factor CR to SR}}$$

Validation of W/top background estimation techniques with M_{eff} distributions (muon channel)

M_{eff} distribution in W R



M_{eff} distribution in T R



Data and Monte Carlo show good agreement.

QCD background estimation in the signal region

Matrix method

- Isolation criteria for the lepton are relaxed $\Rightarrow$ *loose* control sample (common SUSY selection cuts called *tight*)
- Events in signal/loose control sample are split into two categories: not QCD events $\Rightarrow$ *real*, and QCD events $\Rightarrow$ *fake*

$$\begin{aligned} N^{obs}_{tight} &= N^{real}_{tight} + N^{fake}_{tight} \\ N^{obs}_{loose\ not\ tight} &= (1/\epsilon^{real} - 1)N^{real}_{tight} + (1/\epsilon^{fake} - 1)N^{fake}_{tight} \end{aligned}$$

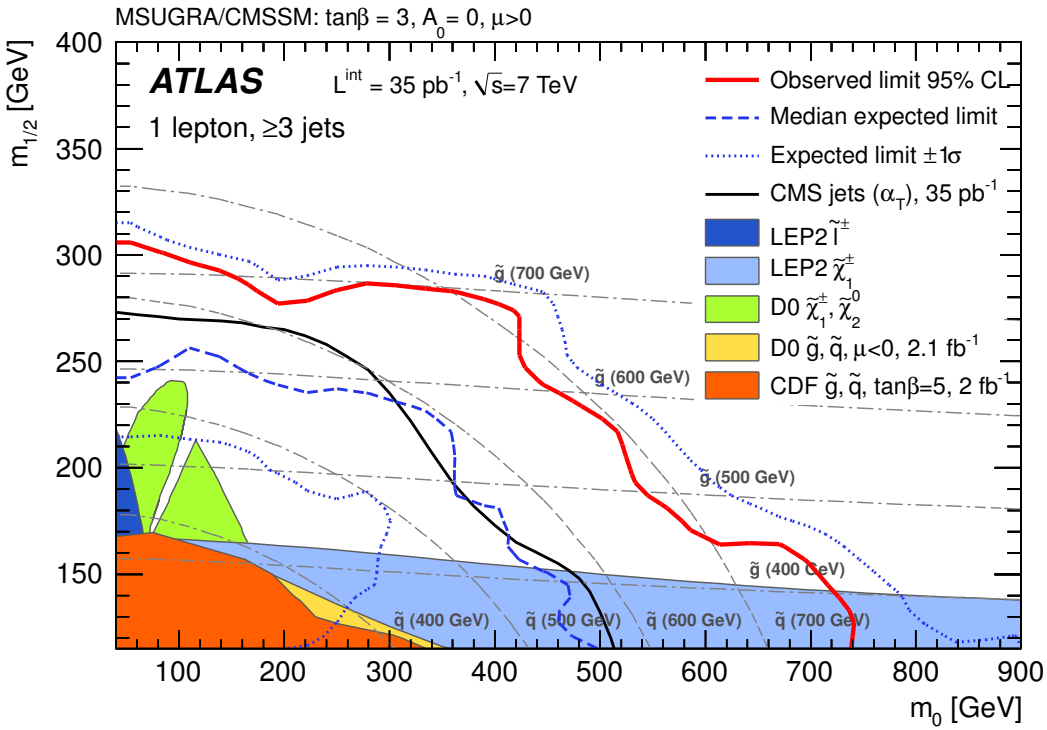
- QCD events in S R:

$$N^{fake}_{tight} = \frac{N^{obs}_{loose\ not\ tight} - (1/\epsilon^{real} - 1)N^{obs}_{tight}}{1/\epsilon^{fake} - 1/\epsilon^{real}}$$

	electron channel	muon channel
ϵ^{real} is taken from MC:	$\epsilon^{real} \sim 0.9 - 1.0$	
ϵ^{fake} is measured in Q R:	$\epsilon^{fake} \sim 0.2 - 0.3$	
Estimated QCD BG in signal region:	$N^{tight}_{fake} < 0.3$ events	$N^{tight}_{fake} < 0.5$ events

A summary: SUSY exclusions plot (35 pb^{-1})

All information (background estimation results, data, extrapolation factor from W/T R to signal region, systematics) is put into a profile likelihood ratio test $\rightarrow$ SUSY exclusion plot in 1-lepton channel



channel	observed events	sum fitted BG events	fitted top	fitted WZ	fitted QCD
muon	1	2.25 ± 0.94	1.76 ± 0.67	0.49 ± 0.36	$0.0^{+0.5}_{-0.0}$
electron	1	1.81 ± 0.75	1.34 ± 0.52	0.47 ± 0.40	$0.0^{+0.3}_{-0.0}$

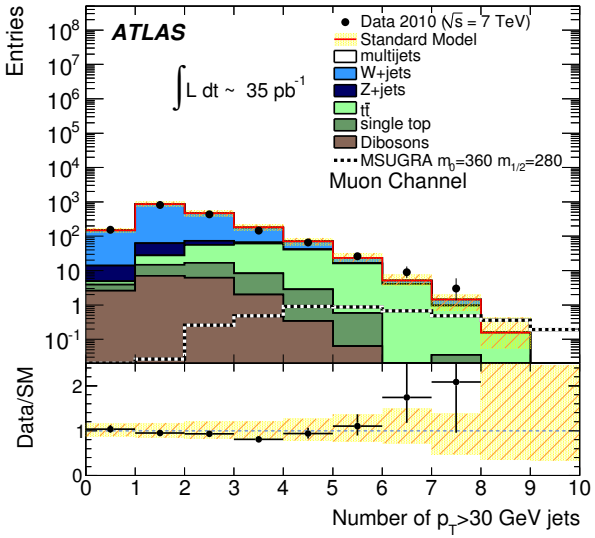
Publication of SUSY search results in 1-lepton channel:
Search for supersymmetry using final states with one lepton, jets, and missing transverse momentum with the ATLAS detector in $\sqrt{s} = 7$ *TeV* pp collisions (arXiv:1102.2357v2 [hep-ex], accepted by PRL)

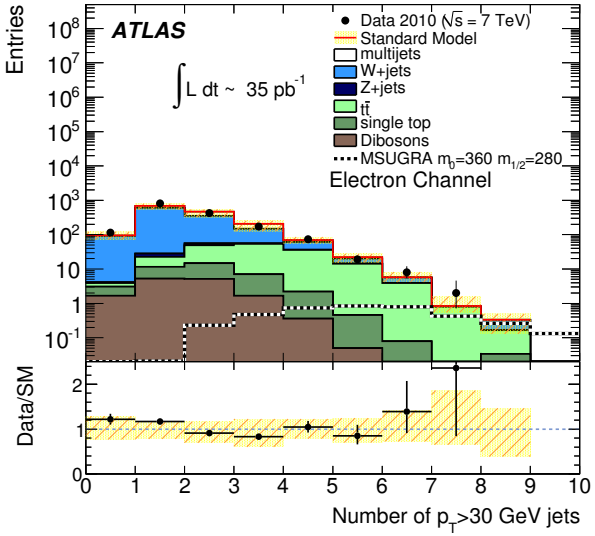
Back-up

Signal selection cuts in the 1-lepton + 3 jets channel

Definition of the channel

1. One isolated lepton with $p_T > 20\ GeV$ (additional requirement for plots: $E_T^{miss} > 80\ GeV$)





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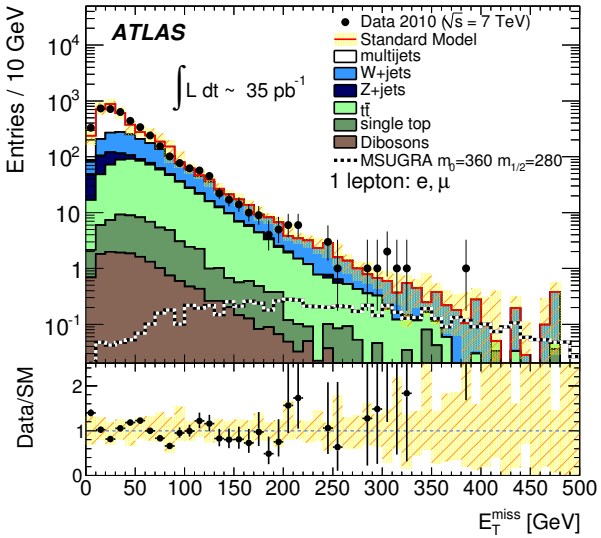

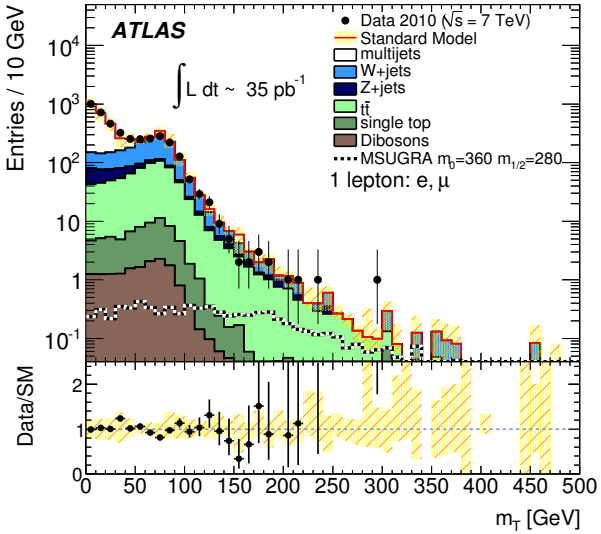

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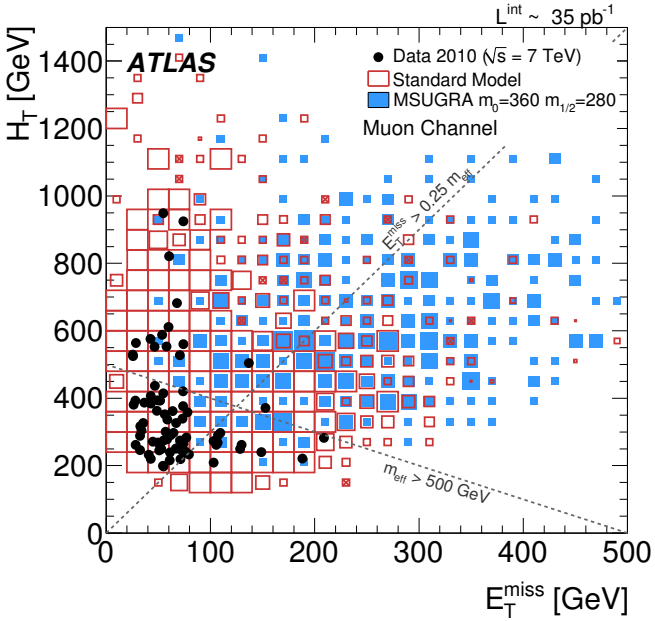
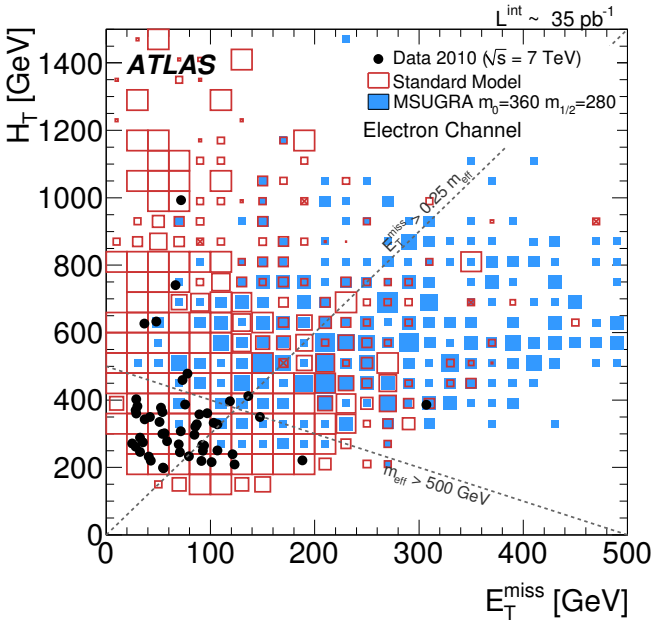
Background reduction

3. $\Delta\phi(jet, E_T^{miss}) > 0.2$
   - Suppression of QCD BG with mismeasured jet transverse momentum
4. $E_T^{miss} > 125\ GeV$
5. $M_T > 100\ GeV$ with
   $M_T = \sqrt{2 \cdot p_T^l \cdot E_T^{miss} \cdot (1 - \cos(\Delta\phi(l, E_T^{miss})))}$
   - Suppression of W and semileptonic $t\bar{t}$ events
6. $E_T^{miss} > 0.25 M_{eff}$ with $M_{eff} = p_T^l + E_T^{miss} + \sum p_T^{jet}$
   - Large E_T^{miss} contribution to M_{eff} in signal events

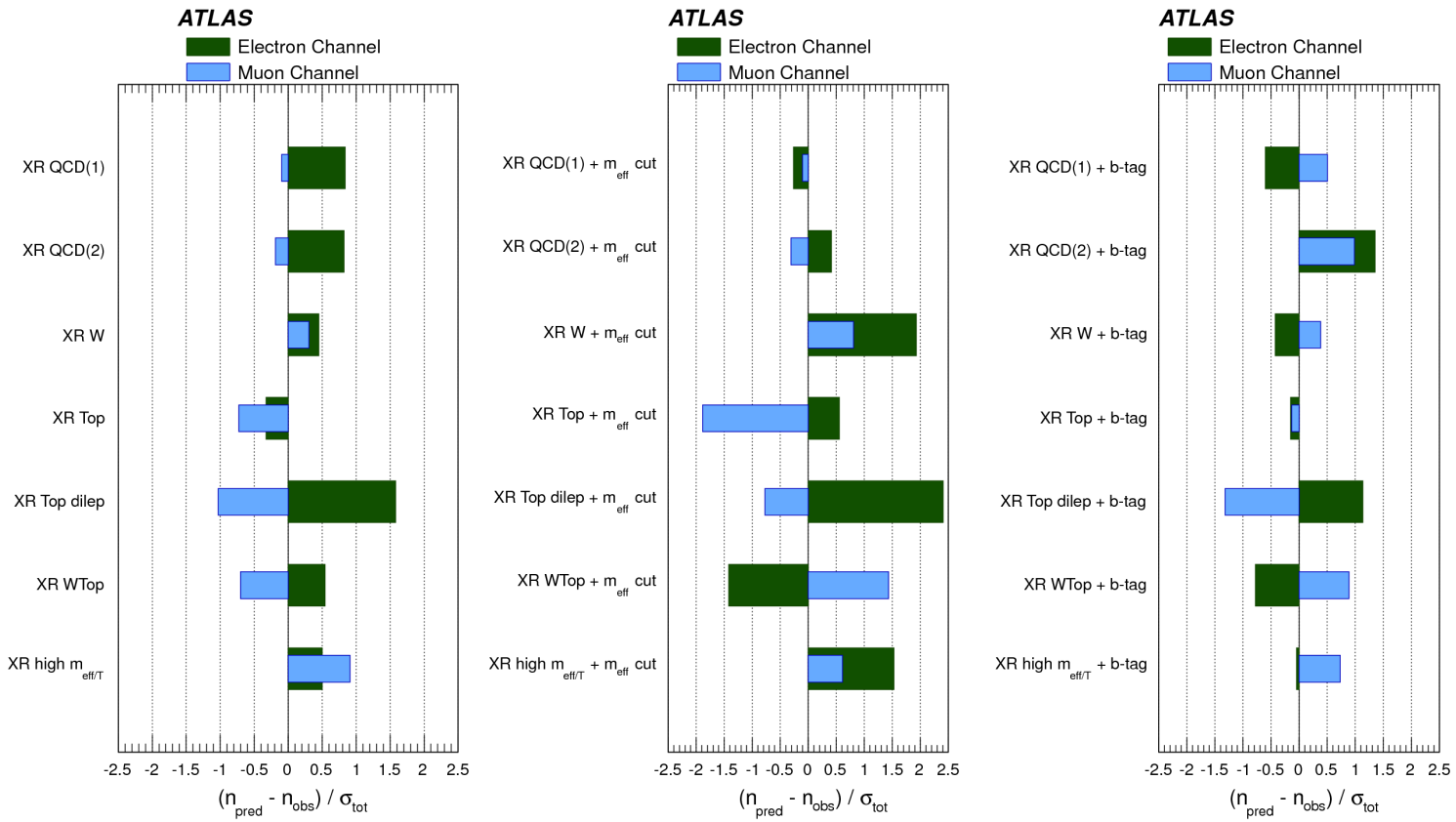




Systematic uncertainties on background estimation - most important contributions

- Monte Carlo modeling of the shapes of the E_T^{miss} and M_T distributions in control and signal regions
  Determined by comparing different Monte Carlo generators and by varying the internal generator parameters
- Finite statistics in control regions
- Experimental uncertainties
  Most important: jet energy scale uncertainty , b-tagging uncertainty, uncertainty on luminosity

Validation of the fit results in extra control regions



The number of observed events is compared with the number of predicted events (by a nominal background fit) in additional control regions (XR). σ_{tot} is the quadratic sum of the extrapolated fit uncertainty and the statistical uncertainty of data and Monte Carlo in each XR control region. Left: No further requirements, middle: an additional cut on $M_{eff} > 500\ GeV$, right: at least one b-jet had to be identified in addition to the left plot.

Results in 1-lepton channel detailed

Electron channel	Signal region	Top region	W region	QCD region
Observed events	1	80	202	1464
Fitted top events	1.34 ± 0.52 (1.29)	65 ± 12 (63)	32 ± 16 (31)	40 ± 11
Fitted W/Z events	0.47 ± 0.40 (0.46)	11.2 ± 4.6 (10.2)	161 ± 27 (146)	170 ± 34
Fitted QCD events	$0.0^{+0.3}_{-0.0}$	3.7 ± 7.6	9 ± 20	1254 ± 51
Fitted sum of background events	1.81 ± 0.75	80 ± 9	202 ± 14	1464 ± 38

Muon channel	Signal region	Top region	W region	QCD region
Observed events	1	93	165	346
Fitted top events	1.76 ± 0.67 (1.39)	85 ± 11 (67)	42 ± 19 (33)	50 ± 10
Fitted W/Z events	0.49 ± 0.36 (0.71)	7.7 ± 3.3 (11.6)	120 ± 26 (166)	71 ± 16
Fitted QCD events	$0.0^{+0.5}_{-0.0}$	0.3 ± 1.2	3 ± 12	225 ± 22
Fitted sum of background events	2.25 ± 0.94	93 ± 10	165 ± 13	346 ± 19

SUSY exclusion plot (large)