Search for direct production of sleptons in proton-proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector

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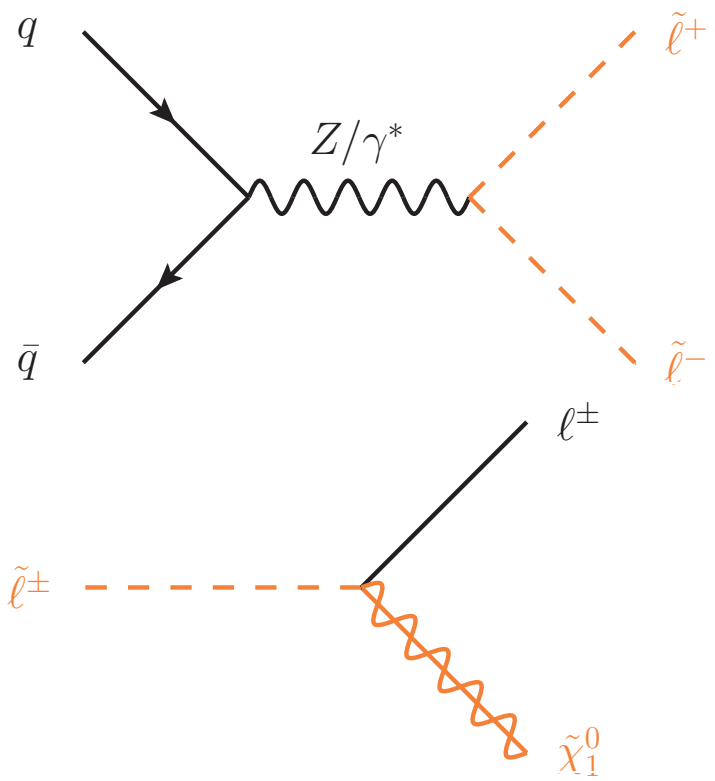
Supersymmetry (SUSY) - a very brief introduction

- Symmetry between fermions and bosons.
- Every SM particle accompanied by a superpartner (sparticle) differing by $\frac{1}{2}$ in spin. In this talk we will meet two sparticles:
  - **Sleptons** ($\tilde{\ell}$): scalars, partners of the SM leptons.
  - The lightest **neutralino** ($\tilde{\chi}_1^0$): spin-$\frac{1}{2}$, mixed state of the superpartners of the neutral EW gauge bosons (gauginos) and Higgs boson(s) (higgsinos), good dark matter candidate.
- Able to solve several Standard Model problems; hierarchy problem, dark matter, gauge coupling unification.
- **But:** not seen in any experiment.

Direct production of sleptons

- A pair of sleptons produced by $q\bar{q}$ annihilation.
- Simplified model: Each slepton decays to its SM lepton partner and the lightest neutralino ($\tilde{\chi}_1^0$) with 100% branching ratio.
- Neutralinos assumed to be stable and escape the detector without leaving any trace.
- This means that we are looking for final states with two leptons (e^+e^- or $\mu^+\mu^-$) and missing transverse energy.

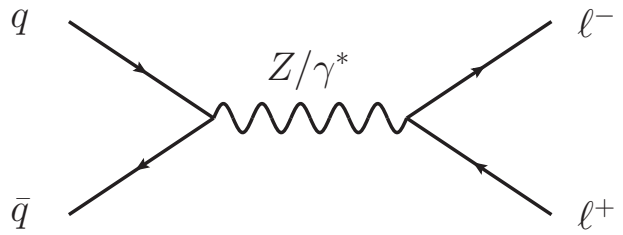


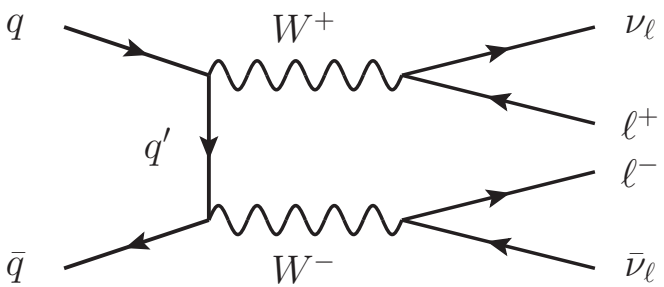
Standard Model backgrounds

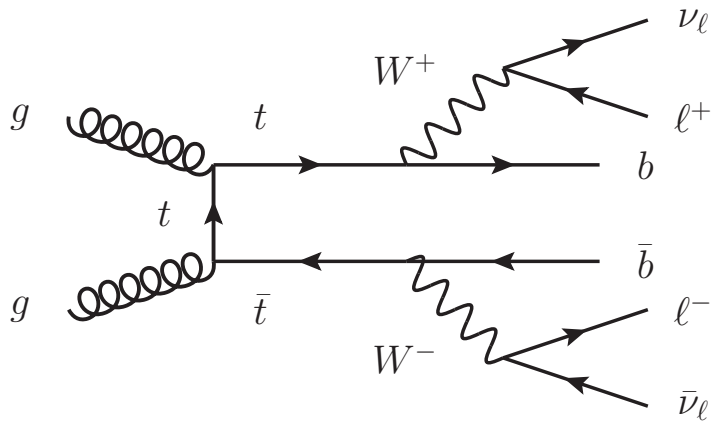
Background process: A process that gives the same signature in the detector as the signal process, i.e. e^+e^- or $\mu^+\mu^-$ and missing transverse energy in this analysis.

Most important backgrounds:

- Z+jets
- $t\bar{t}$
- Di-bosons (W^+W^-, ZZ)







Kinematic variables

Basic variables measured by the detector for each particle/jet:

- Transverse momentum, p_T.
- Azimuthal angle, ϕ.
- Pseudo-rapidity, η.

Variables derived from the basic ones:

- Missing transverse energy, $E_T^{miss} = |\sum \vec{p}_T|$.
- Invariant mass of two leptons,

$$m_{\ell\ell} = 2p_{T1}p_{T2}(\cosh(\eta_1 - \eta_2) - \cos(\phi_1 - \phi_2)).$$

- M_{T2} (stransverse mass),

$$M_{T2} = \min_{\mathbf{p}_T^{miss} = \mathbf{q}_T^{\chi 1} + \mathbf{q}_T^{\chi 2}} \{\max[\, m_T(\mathbf{p}_T^{\ell_1}, \mathbf{q}_T^{\chi 1}; m_\chi), m_T(\mathbf{p}_T^{\ell_2}, \mathbf{q}_T^{\chi 2}; m_\chi)\,]\}\,.$$

Pre-selection of events

Exactly 2 SF OS signal leptons

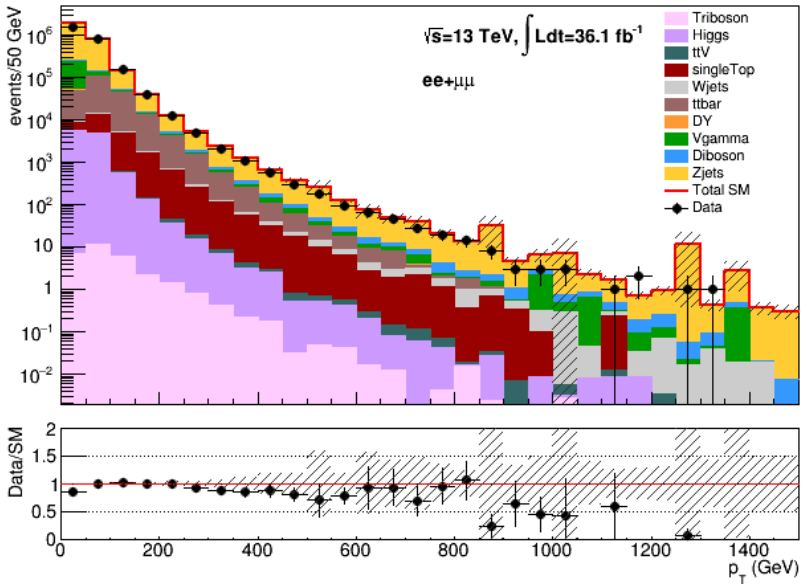
$p_T^{lep1} > 25$ GeV & $p_T^{lep2} > 20$ GeV

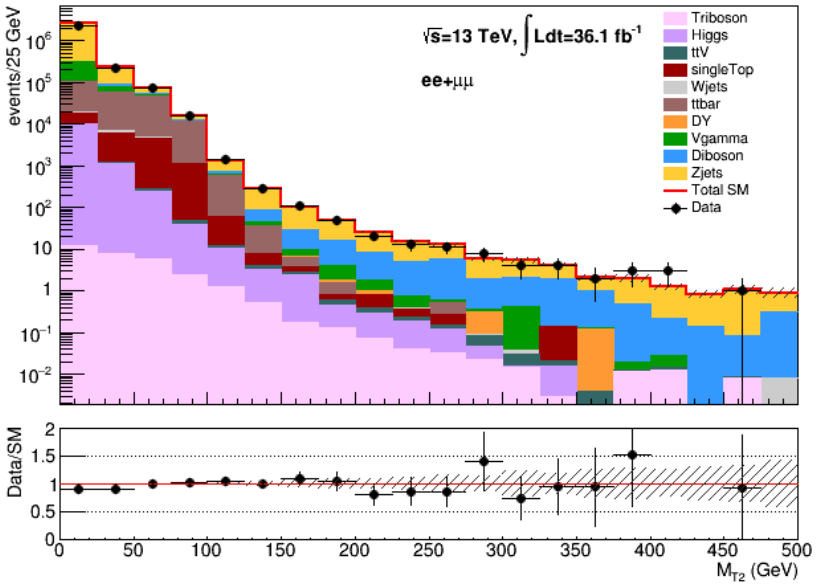
Lowest unprescaled di-electron and di-muon triggers

$m_{\ell\ell} > 40$ GeV

Z − veto: $|m_Z - m_{\ell\ell}| > 20$ GeV

Purpose: Selecting a high quality set of events that can be regarded as interesting based on the physical properties of the signal process.





Signal region definitions

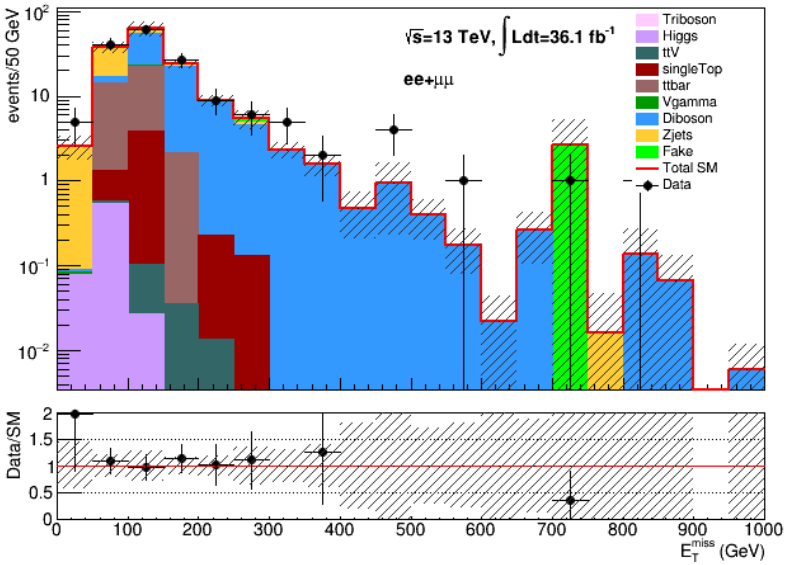
- **Purpose:** Selecting events such that we are sensitive to the signal process.
- Event selection optimised by studying simulated signals for 49 different combinations of $m_{\tilde{\ell}}$ and $m_{\tilde{\chi}_1^0}$.
- Two SRs designed to target a wide range of signal points:
  - **SR-loose:** For signal points with low slepton masses.
  - **SR-tight:** For signal points with higher slepton masses.

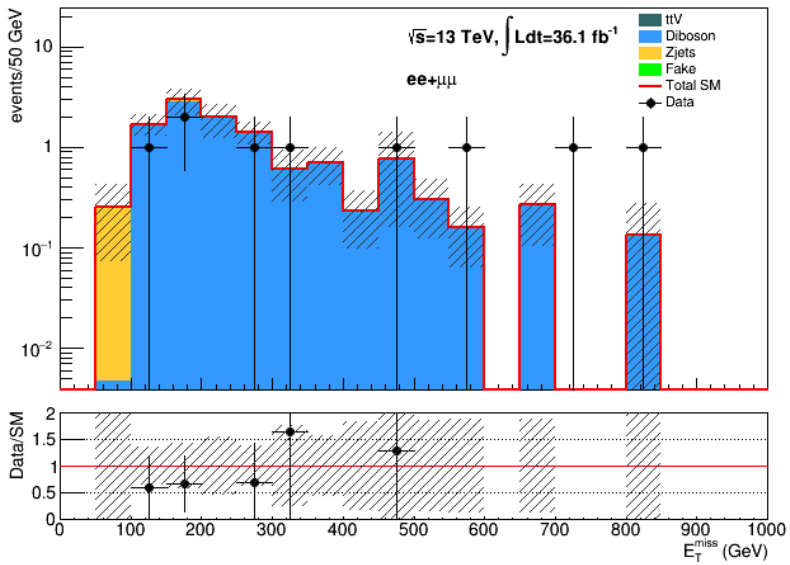
	SR-loose	SR-tight
Central b-jets	0_{20}	0_{20}
Central light jets	0_{60}	0_{60}
$m_{\ell\ell}$ (GeV)	> 111	> 300
M_{T2} (GeV)	> 100	> 130

Results of the search

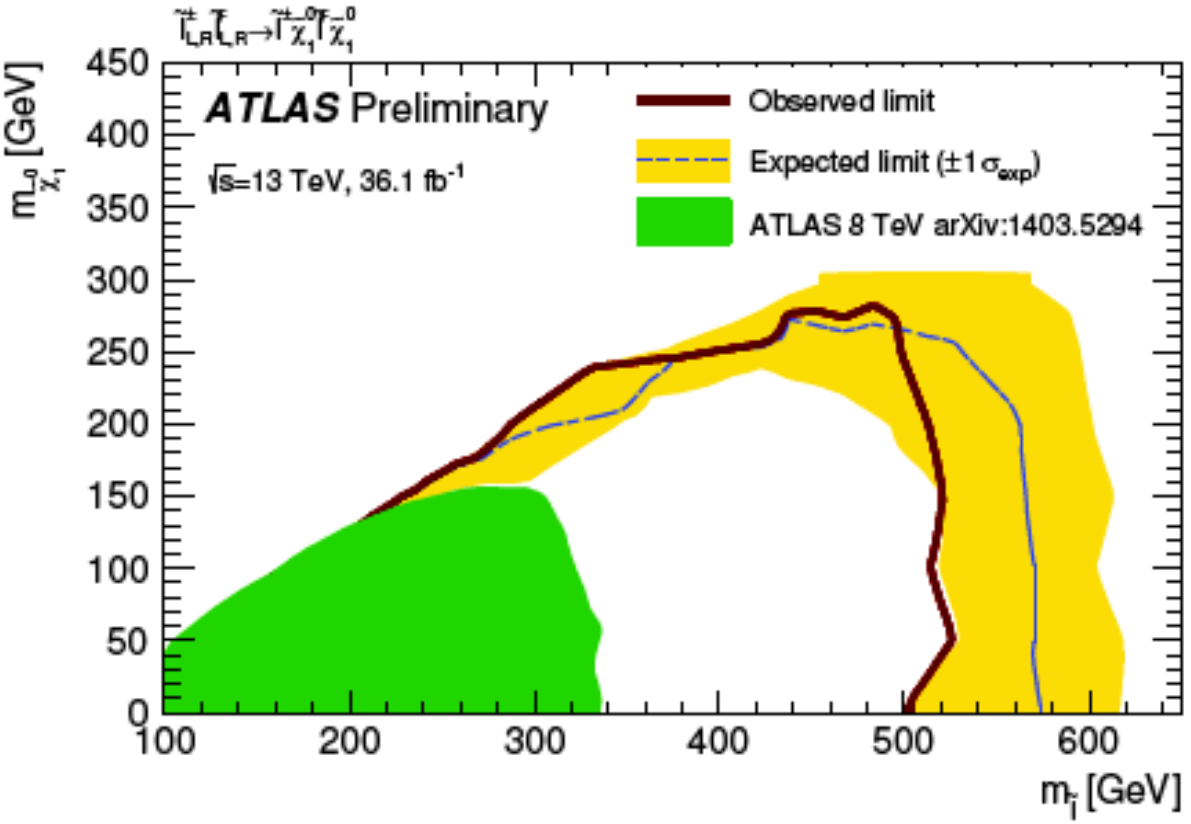
	SR-loose	SR-tight
Observed events	163	9
Estimated background	149.46 ± 14.23	11.62 ± 1.54
Z+jets	31.65 ± 4.89	0.36 ± 0.23
Diboson	74.02 ± 5.90	11.21 ± 1.44
$t\bar{t}$	33.36 ± 3.39	0.00 ± 0.00
Fakes	4.07 ± 11.46	0.05 ± 0.50
Other	6.36 ± 1.62	0.01 ± 0.00

No significant excess observed!





Exclusion limits



NB: exclusion limits not made by me.

Summary

- Have done a search for direct production of sleptons by studying two-lepton final states and missing energy in the data set collected by ATLAS over the last two years.
- No significant excess above the expected Standard Model background is observed.
- Exclusion limits on $m_{\tilde{\ell}}$ and $m_{\tilde{\chi}_1^0}$ significantly extended.
- More results from the ATLAS SUSY EWK 2/3L group can be found here: http://cds.cern.ch/record/2267406/files/ATLAS-CONF-2017-039.pdf