SUSY discovery potential of the ATLAS detector at an upgraded LHC

Melbourne – SUSY 2016

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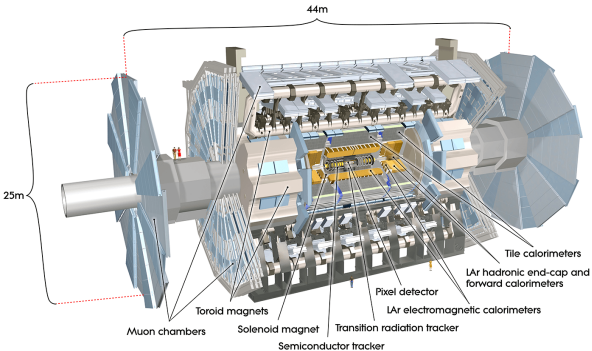
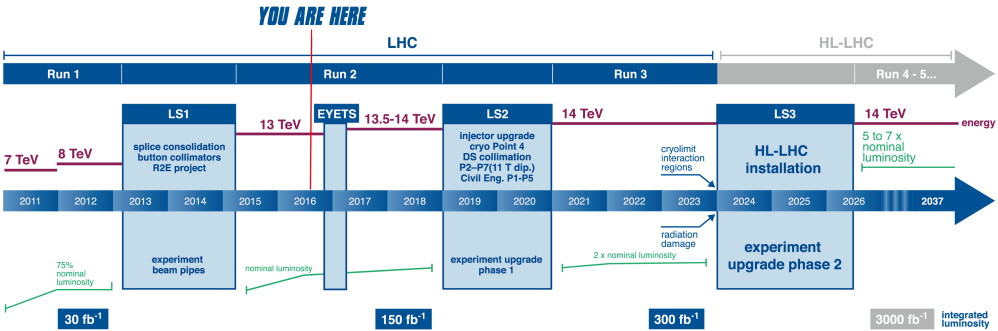
Current status of ATLAS and considered upgrades



- 4π coverage multi purpose detector aimed at generic searches
- Build to withstand the LHC design instantaneous luminosity of 10^{34} cm^{-2} s^{-1} at a Level 1 trigger rate of 100 kHz
- Estimated to be working as is with minor upgrades until 2024
- For HL-HLC Redesign of the **Inner detector (ITK)** (TRT is dead long live the TRT)
- Replacement of **forward calorimeters**
- Reinforcement of the **forward muon system** via TGC/Micromegas combination
- **Trigger redesign** (L0/L1 electronics)

Current LHC Luminosity and projections for HL-LHC



End of Run III : 300 fb^{-1} at $\sqrt{s} = 13 \leftrightarrow 14$TeV at $\langle\mu\rangle \approx 60$

HL-LHC : 3000 fb^{-1} at $\sqrt{s} = \quad 14 \quad$ TeV at $\langle\mu\rangle \approx 140$

SUSY or how to get Beyond Standard Model

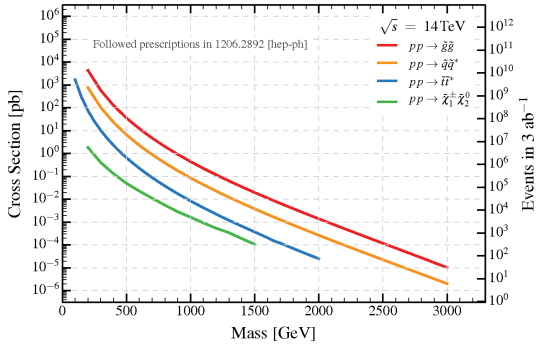
- Standard Model is an extremely precise theory but some discrepancies gives clues that it might not be it
  - Hierarchy problem due to the "low" scalar boson mass
  - $m_\nu \neq 0$ (Dirac or Majorana?)
  - Non inclusion of Gravity into the models
  - Cosmological predictions falls short to model the current known universe

- Supersymmetry can provide some solutions to
  - Hierarchy problem by additional corrections to the scalar boson mass
  - Possibly introduction of gravity into the framework
  - Dark matter candidate via $\tilde{\chi}^0$
  - Additional fields give leeway for cosmological models

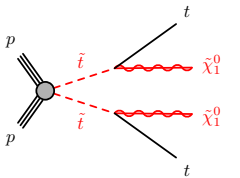
But, so far, nothing found yet...

Assumptions at 14TeV 3000fb^{-1}

- SUSY is R-Parity conserving
- $\tilde{\chi}_1^0$ is the lightest SUSY particle
- Unless specified all background uncertainties are estimated at 30%
- 100% Branching ratios for all processes
- Mass constrains depends on the assumed SUSY mass spectrum



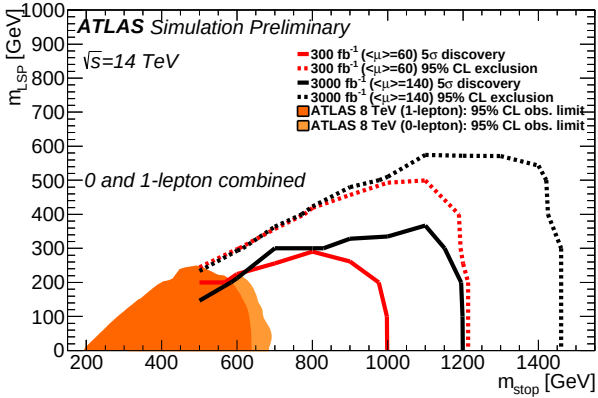
Direct $\tilde{t}$ pair production



- 0 lepton | $\geq$6 jets | $\geq$2 b-jet | High E_T^{miss} $\rightarrow$
- 1 lepton | $\geq$4 jets | $\geq$1 b-jet | High E_T^{miss}

$(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0})$	(800, 100)	(1100, 100)
$t\bar{t}$	69 ± 13	5.7 ± 3.4
$t\bar{t} + W$	5 ± 1	0.8 ± 0.6
$t\bar{t} + Z$	38 ± 5	3.9 ± 1.5
W+ jets	3 ± 3	negligible
Z+ jets	14 ± 4	1.8 ± 1.3
Total bkg	129 ± 15	12.2 ± 3.9
Signal	457 ± 13	46.0 ± 1.4

- Naturalness requires stop/sbottom mass to be $<\approx 1$ TeV
- Consider non compressed $|\tilde{t}_1 - \tilde{\chi}_1^0| > m_t$
- 5σ discovery potential up to 1 TeV with 300 fb^{-1} and 1.2 TeV with 3000 fb^{-1} for combined results



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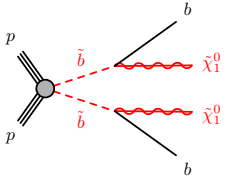
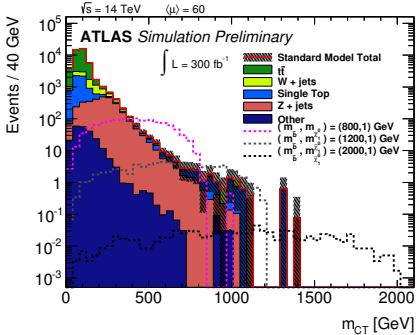
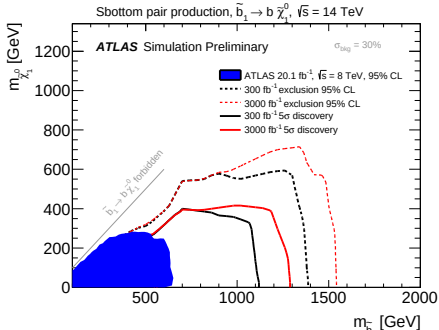
Direct $\tilde{b}$ pair production



- 0 leptons | 2 b-jets $p_T > 50$ GeV making use of the boost corrected co-transverse mass to discriminate $t\bar{t}$ | $m_{CT}^{max} = \frac{m^2(\tilde{b}) - m^2(\tilde{\chi}_1^0)}{m(\tilde{b})}$
- After this selection main background left $Z(\rightarrow \nu\nu) + b\bar{b}$ with some $t\bar{t}V$ and VV

- 5σ discovery potential up to 1.1 TeV with 300 fb^{-1} and 1.3 TeV with 3000 fb^{-1}





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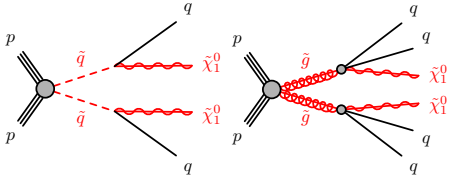
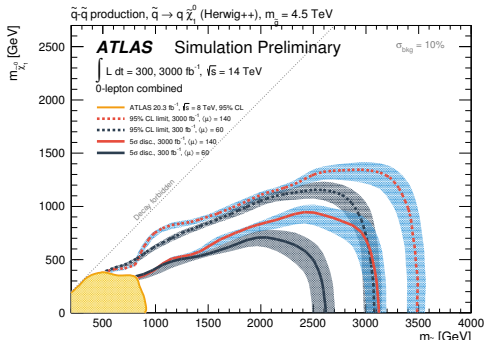
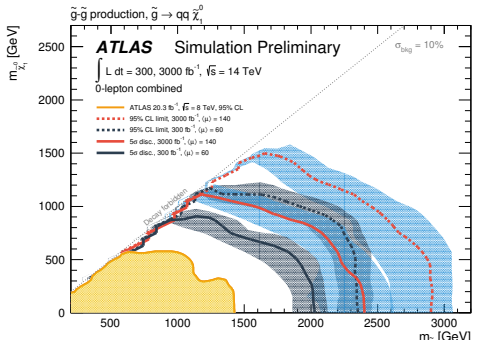
Direct $\tilde{q}$ and $\tilde{g}$ production



- 9 SR for light flavour $\tilde{q}$ and $\tilde{g}$
- ≥ 2 to ≥ 6 jets
- Based on 8 TeV publication optimized for Run 3 with $m_{\text{eff}=E_{\text{T}}^{\text{miss}}} + \sum \left| p_{\text{T}}^{\text{jet}} \right|$
- https://arxiv.org/abs/1405.7875
- large uncertainty in high mass $\tilde{g}$ case is from PDF uncertainties and not signal specific





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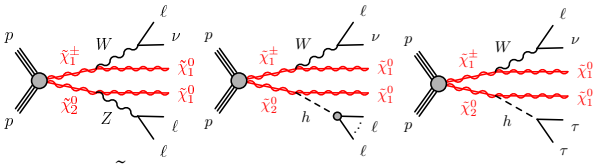
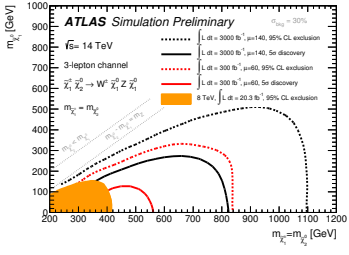
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production – *WZ* / *Wh* mediated



- All $\tilde{l}$ and $\tilde{\nu}$ assumed to be heavy

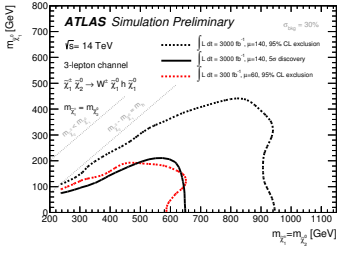
- *WZ*
  - 3 leptons + leptonic τ decays | High E_T^{miss}
  - 0 *b*-jet | SFOS for *Z* selection | m_T
- *Wh*
  - 3 leptons SFOS veto
  - 1 lepton + 2 τ OS | High E_T^{miss}

WZ



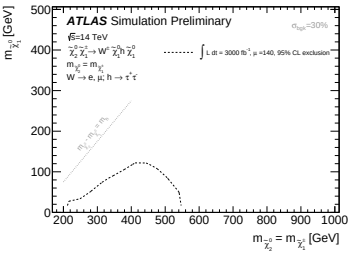
5σ 820 GeV 3 ab^{-1}

3leptons



5σ 650 GeV 3 ab^{-1}

1lepton 2τ



Excl 550 GeV 3 ab^{-1}

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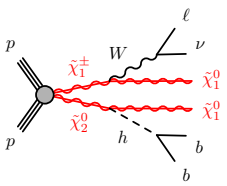
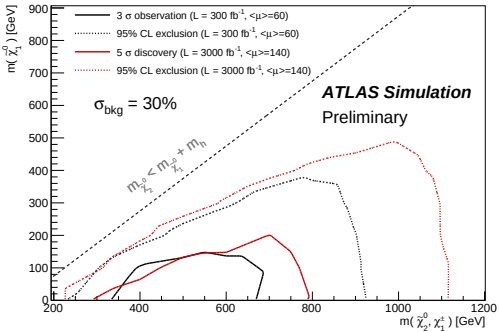
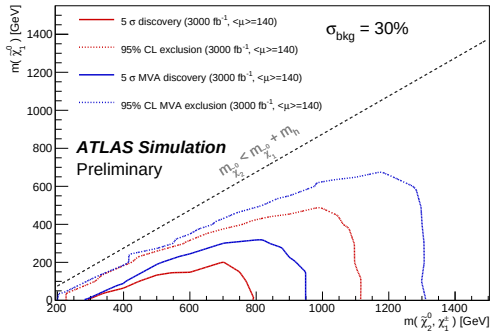
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production – *Wh* mediated



- Making use of m_T and m_{CT}
- 1 lepton | $\geq$4 jets | $\geq$1 *b*-jet | High E_T^{miss}
- Two techniques
  - Cut and count
  - MVA with BDT: m_{CT}, m_T, E_T^{miss}, leading *b*-jet p_T, Δr(leading *b*-jet, sub-leading *b*-jet), $\Delta\phi$ (leading *b*-jet, E_T^{miss})





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Conclusions

- ATLAS in the context HL-HLC has good prospect of finding SUSY if it hides in the ≈ 1TeV scale
- Many SUSY channels are being covered by ATLAS currently and in the context of the HL-HLC upgrade
- If SUSY candidates are discovered by then ATLAS at the HL-LHC can provide precise measurements of their properties
- Follow our latest SUSY searches results at https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

Thank you for your attention!