ATLAS SUSY Input to the European Strategy Document

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Introduction

ATLAS has produced a document for the Krakow meeting (10-12 Sep, 2012) of the European Strategy for Particle Physics (ATL-PHYS-PUB-2012-001)

Outlines the physics accessible with 3000 fb^{-1} at $\sqrt{s}$ = 14 TeV at the LHC

Today:
5 fb^{-1} @ 7 TeV
~15 fb^{-1} @ 8 TeV
Peak lumi ~ 7.7 x 10^{33}

→ LS1: 2013/14 →

2015-2018:
$\sqrt{s}$ = 13-14 TeV
Lumi ~ 1 x 10^{34}

→ LS2: 2018 →

2019-2021:
$\sqrt{s}$ = 14 TeV
Lumi ~ 2 x 10^{34}
300 fb^{-1} total

↓ LS3: 2022 ↓

2023-2030:
$\sqrt{s}$ = 14 TeV
Lumi ~ 5 x 10^{34}
3000 fb^{-1} total

ATLAS European Strategy Document

- Higgs
  - Spin/CP
  - Higgs couplings
- Vector boson scattering
- Exotics
  - ttbar resonances
  - dilepton resonances
- FCNC in top decays
- SUSY discovery potential
  - Squarks/gluinos
  - Scalar top
  - Chargino-neutralino

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Focus of this talk

Aside: “Natural SUSY”

K.G.Wilson, PRD3 (1971) 1818

- The Higgs looks real, but now we're faced with an old puzzle: fine-tuning
- SUSY → favorite solution, but no sign so far
- Renewed focus on minimal SUSY requirements to protect the Higgs Mass: “natural SUSY”

This discussion can be summarized by saying that mass or symmetry-breaking terms must be “protected” from large corrections at large momenta due to various interactions (electromagnetic, weak, or strong). A symmetry-breaking term, such as $h_{1\lambda}$, $h_{2\lambda}$, or $h_{3\lambda}$, is protected if, in the renormalization-group equation for $h_{1\lambda}$, $h_{2\lambda}$, or $h_{3\lambda}$, the right-hand side is proportional to $h_{1\lambda}$, $h_{2\lambda}$, $h_{3\lambda}$ or other small coupling constants even when high-order strong, electromagnetic, or weak corrections are taken into account. The mass terms for the electron and muon and the weak boson, if any, must also be protected. This requirement means that weak interactions cannot be mediated by scalar particles.[36]

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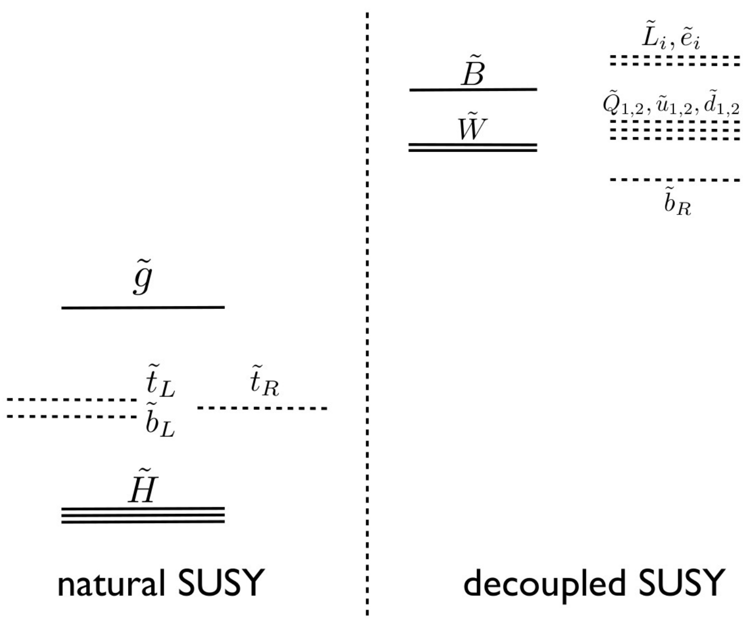


Papucci, Ruderman and Weiler, arXiv:1110.6926

Stop: $$\sqrt{m_{\tilde{t}_1}^2 + m_{\tilde{t}_2}^2} \lesssim 600\,\mathrm{GeV}\frac{\sin\beta}{(1+x_t^2)^{1/2}}\left(\frac{\log(\Lambda/\,\mathrm{TeV})}{3}\right)^{-1/2}\left(\frac{m_h}{120\,\mathrm{GeV}}\right)\left(\frac{\Delta^{-1}}{20\%}\right)^{-1/2}$$

Gluino: $$M_3 \lesssim 900\,\mathrm{GeV}\sin\beta\left(\frac{\log(\Lambda/\,\mathrm{TeV})}{3}\right)^{-1}\left(\frac{m_h}{120\,\mathrm{GeV}}\right)\left(\frac{\Delta^{-1}}{20\%}\right)^{-1/2}$$

Higgsino: $$\mu \lesssim 200\,\mathrm{GeV}\left(\frac{m_h}{120\,\mathrm{GeV}}\right)\left(\frac{\Delta^{-1}}{20\%}\right)^{-1/2}$$

$$\Delta \equiv \frac{2\delta m_H^2}{m_h^2}$$

Monte Carlo

SM backgrounds estimated with smeared truth-level Monte Carlo

- Simple smearing based on best guess of detector performance
- Truth level filters to improve statistical accuracy
- ttbar, W/Z+jets and $WZ^{(*)}$: SHERPA (some ttbar and single-top with MC@NLO)
- $WW^{(*)}$: PYTHIA

SUSY signal generators:

- Generally looking at simplified models
- Squarks/gluinos: Herwig++
- Stop: Herwig++
- Chargino/neutralino: PYTHIA

Cross sections:

- W/Z +jets: NNLO inclusive xsec (FEWZ)
- ttbar: approximate NNLO (HATHOR)
- dibosons: NLO (MCFM)
- SUSY signal: NLO (Prospino)

Systematic uncertainties:

- 30% uncertainty assumed on SM backgrounds

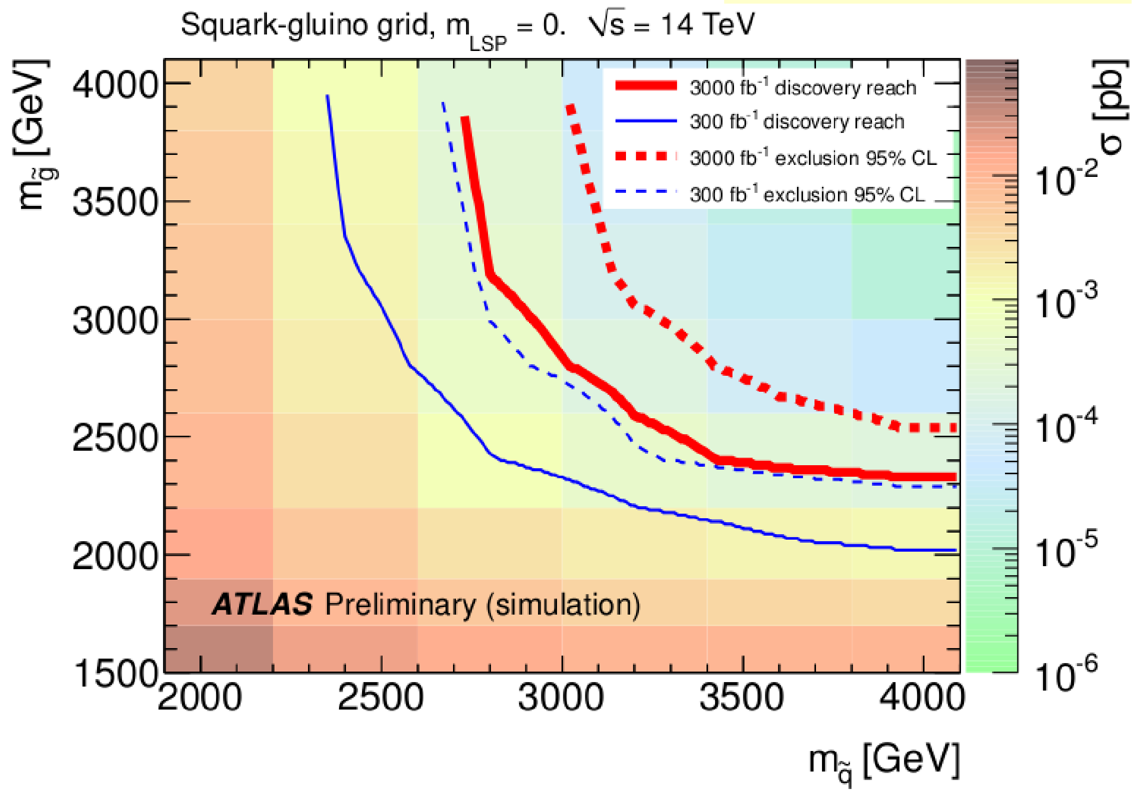
Squarks/gluinos

Weak dependence on LSP mass up to about 1/3 of sq or gl mass

Cuts inspired by 7 TeV analysis:

- Veto e,mu with pt > 20 GeV
- ≥ 4 jets, pt > 60 GeV
- MET/√(HT) > 10 √GeV
- Meff > 2750 GeV

Main backgrounds are Z(νν)+jets and ttbar



Roughly similar conclusions reached in arXiv:1207.4846 (Baer et al)

400-500 GeV improvement in reach going from 300 fb^{-1} to 3000 fb^{-1}

Higgs in SUSY cascade decays

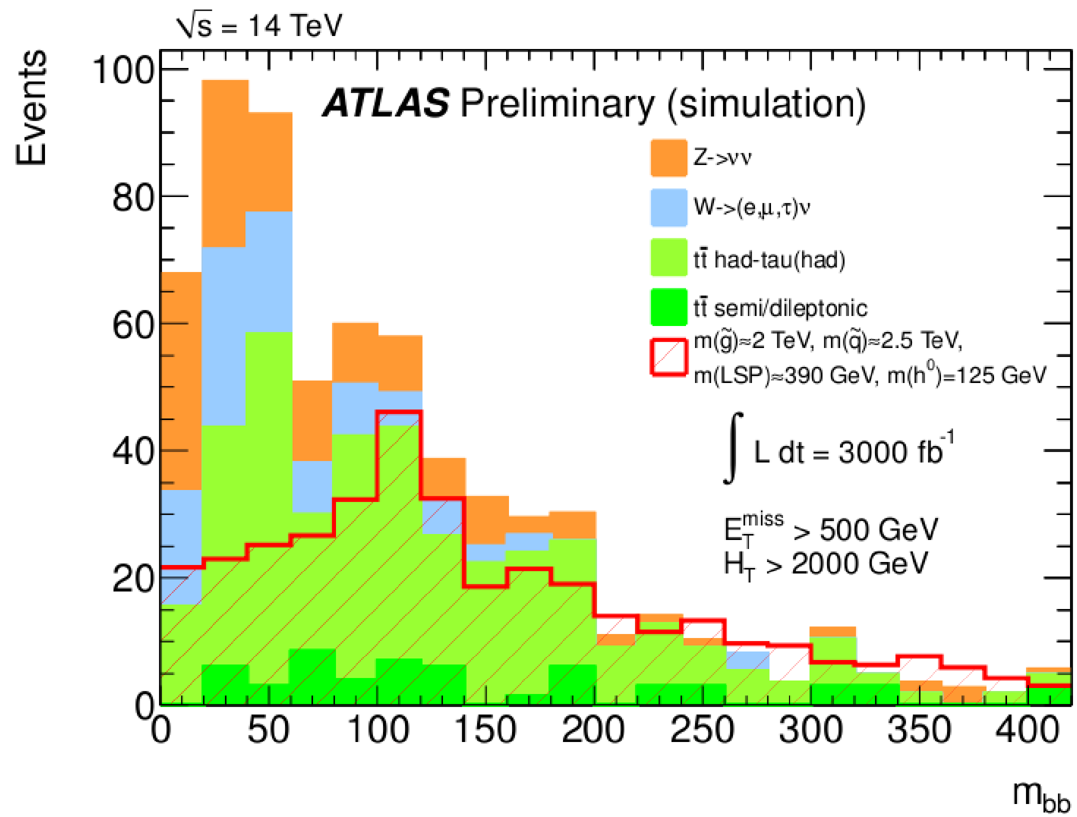
Search for Higgs for cascades with large BR for N2 → h N1

Studied for a MSUGRA benchmark point: m(sq,gl) ~ 2 TeV and m(N1) ~ 390 GeV

Cuts follow squark/gluino search (Meff > 2500 GeV)
Final discriminant is M(bb)

$S/\sqrt{B} \sim 9$

Determine Higgs yield with a precision of ~ 10% for 3000 fb^{-1}



Direct stop production

Two scenarios considered for stop BR's:

- Both stops decay via st → t N1
  - Top quark pair with large MET

- Both stops decay via st → b C1 with C1 → W N1
  - Two soft bjets and two W's (can be virtual)

1-lepton analysis (targeting st → t N1)

- ≥ 4 jets, at least one b-tagged
- Optimize cuts on MET, MT, MET/√HT across the signal plane

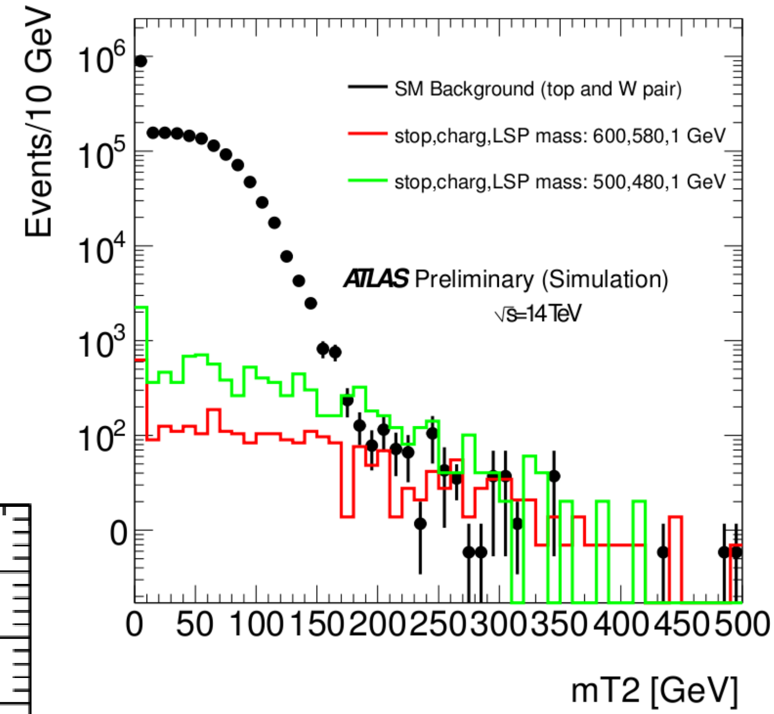
2-lepton analysis (targeting st → b C1)

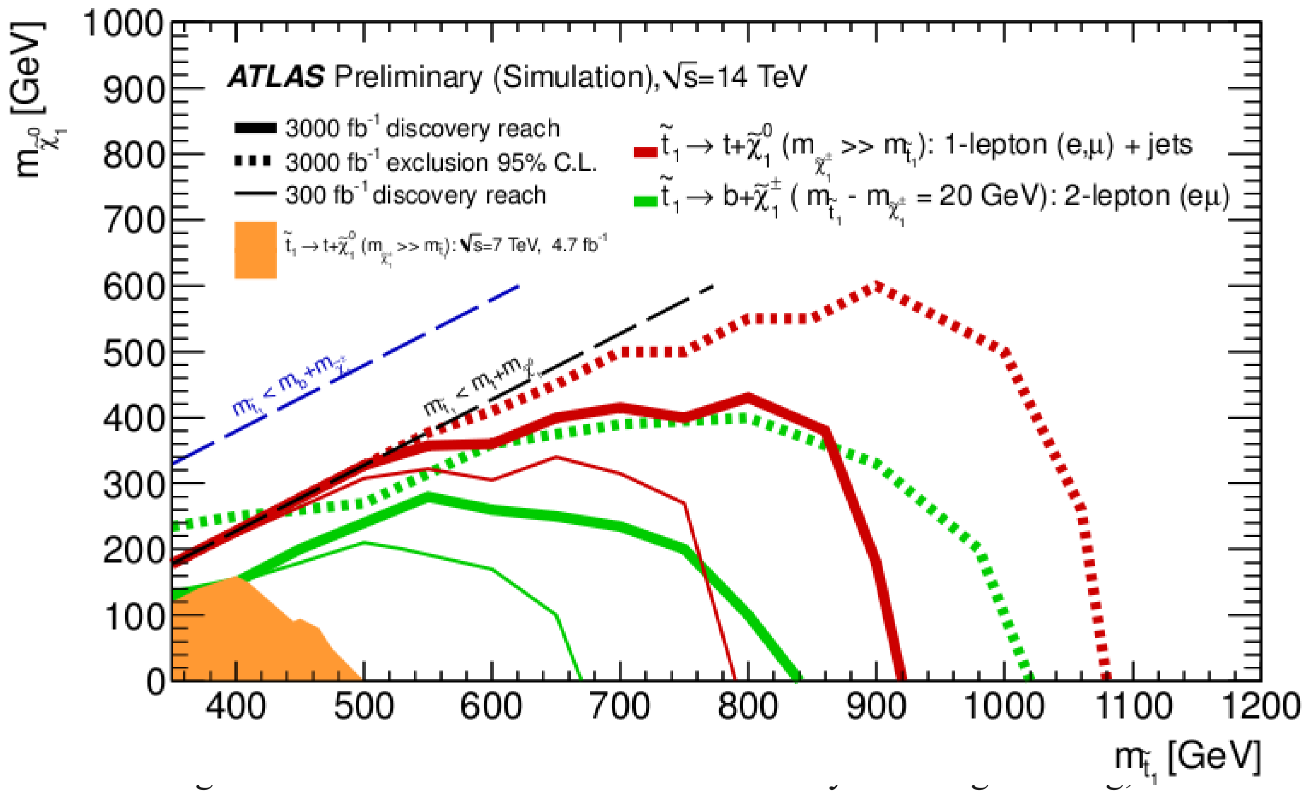
- e+mu with pt > 25 GeV
- Optimize cuts on MT2 and MET + pt(e) + pt(mu) across the signal plane

Main background is ttbar

Direct stop production

MT2 distribution from dilepton analysis





200 GeV increase in stop reach going from 300 to 3000 fb^{-1}

Chargino-Neutralino production

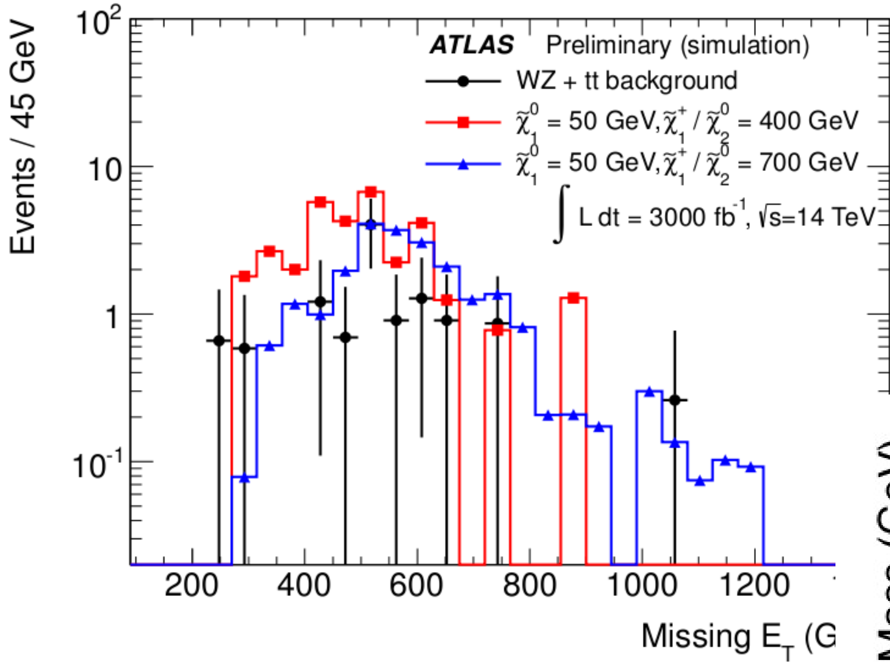
C1 N2 production, followed by C1 → $W^{(*)}$ N1 and N2 → $Z^{(*)}$ N1

Cuts optimized on two benchmark scenarios:
- m(C1)=300 GeV and m(N1)=200 GeV
- m(C1)=700 GeV and m(N1)=200 GeV

Preselection:
- ≥ 3 isolated leptons (e or mu), pt > 25,10,10 GeV, $|\eta| < 2.6$
- m(SFOS pair) > 20 GeV
- MET > 150 GeV

BDT-based optimization using:
- MET
- MT of lepton not forming Z candidate
- lepton pT
- mass and pT of Z candidate
- Sum pt of jets

Chargino-Neutralino production

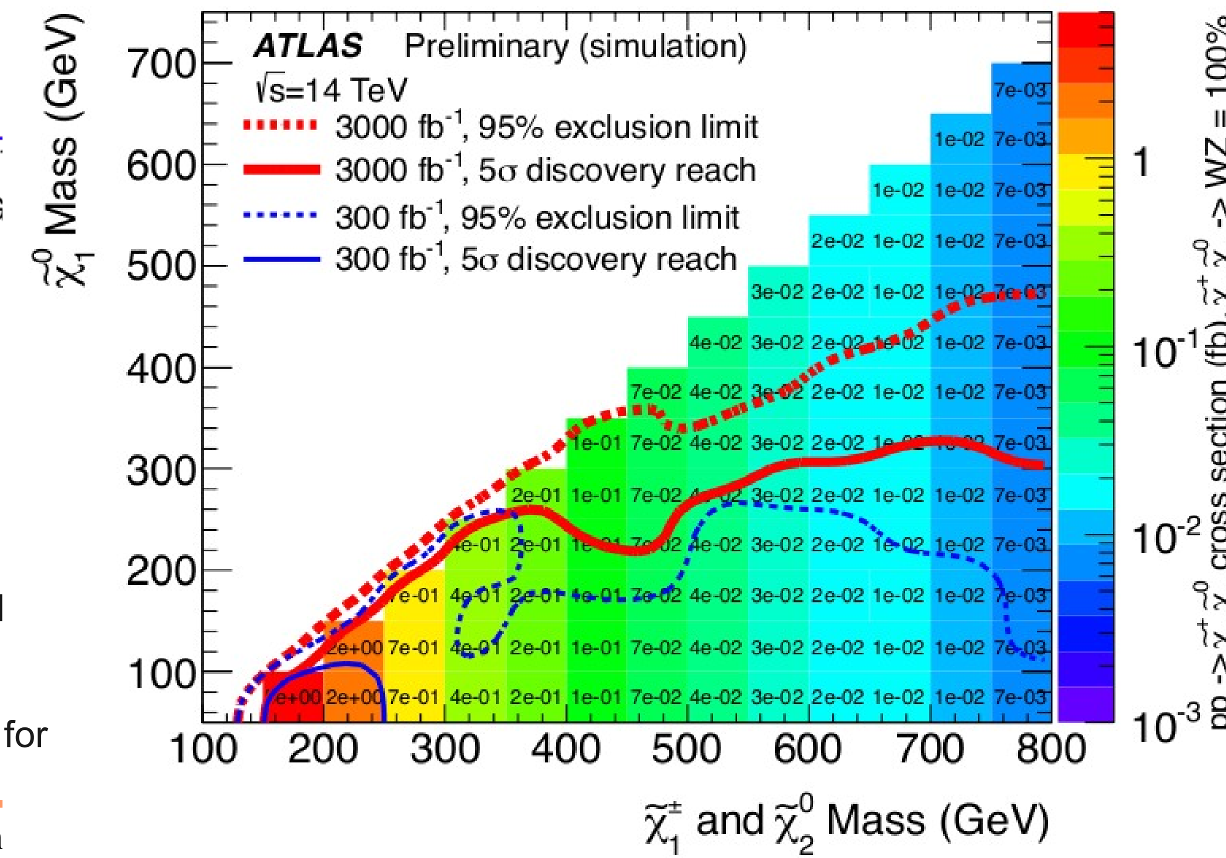


MET after BDT selection

Main backgrounds are WZ and ttbar

Discovery for m(N2,C1) ~ 250 GeV with 300 fb^{-1}

Increases to 800 GeV with 3000 fb^{-1}



Baer et al (arXiv:1207.4846) studied C1 N2 → (W N1) + (h N1)

Wino mass reach of 450 (950) GeV for 300 (3000) fb^{-1}

Summary and outlook

Presented ATLAS SUSY sensitivity improvements from 300 to 3000 fb^{-1} (HL-LHC)

Studies are based on MC truth of the major backgrounds smeared by best guess resolution functions

Some indicative numbers for 5σ discovery reach (low LSP masses):

	300 fb-1	3000 fb-1
m(sq)=m(gl)	2600 GeV	3000 GeV
stop (b C1)	650 GeV	850 GeV
stop (t N1)	780 GeV	920 GeV
C1 N2	250 GeV	800 GeV

Important to remember that this is the result of a first quick look at the problem

These studies will be continued/expanded to develop the Phase 2 LOI