Light stops at the LHC

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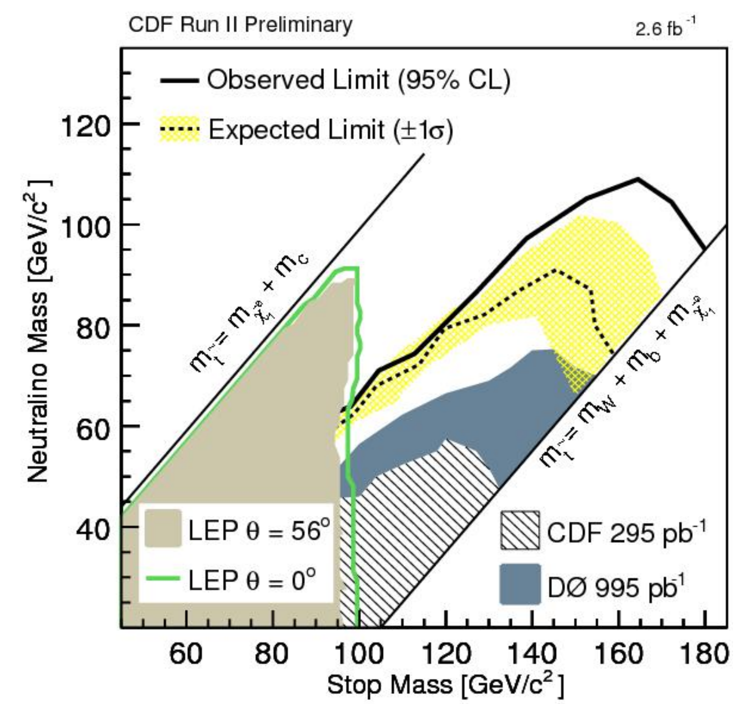
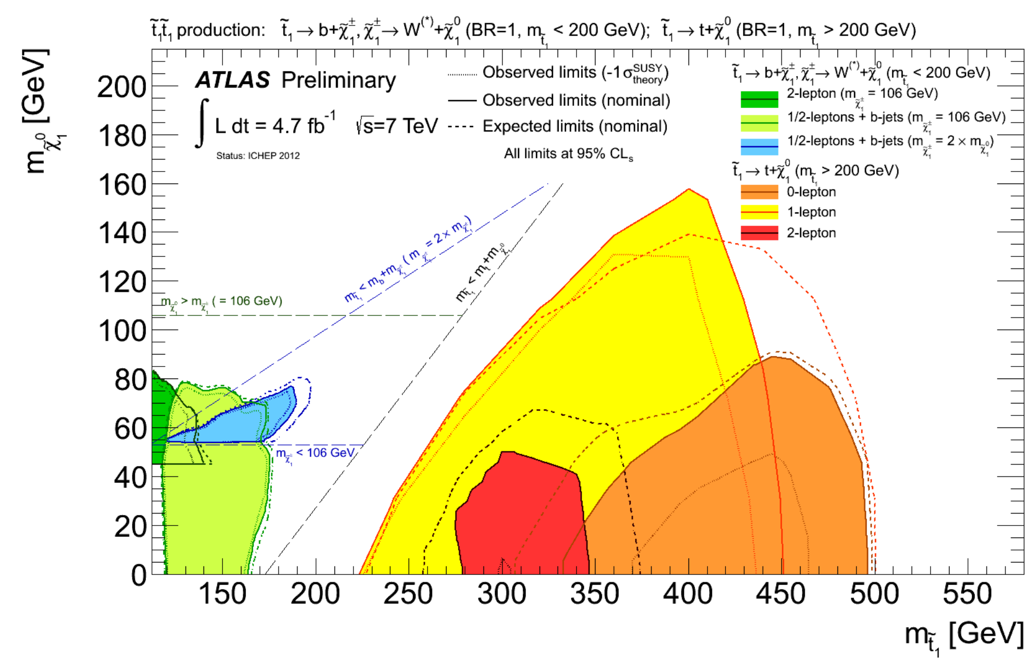
Introduction

- SUSY predicts sparticles around the TeV scale
- ATLAS searches in multijets and large MET channel give bounds on first two generation squarks/gluinos
- degenerate squarks and gluinos must be heavier than 1 TeV
- somewhat unnatural for SUSY
- bounds on third generation sparticles are much weaker

Stop pair production at hadron colliders

- LEP, Tevatron and LHC have searched for scalar tops
- LEP/Tevatron searched for stops decaying into charm and neutralino
- decay channel is difficult to probe at the LHC
- ATLAS considered stop decays into b & chargino or top & neutralino





Stops in coannihilation region

- we consider scalar tops in co-annihilation region

$$\Delta M = m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} \approx \mathcal{O}(10)\,\text{GeV}$$

- co-annihilation region can provide the correct relic abundance

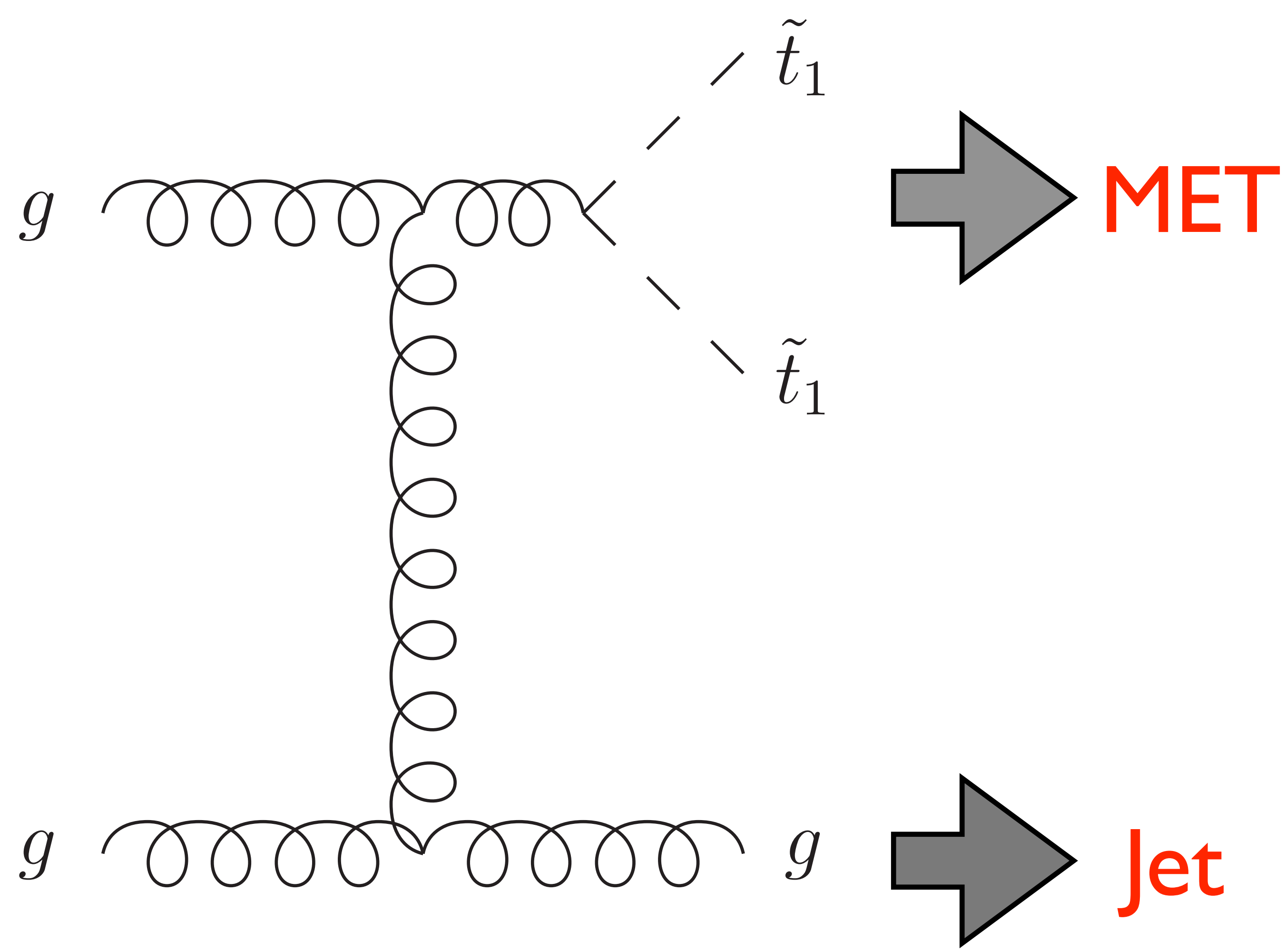
- all three body decays are kinematically closed or suppressed $\tilde{t}_1 \to b\tilde{\chi}_1^0 W, \tilde{t}_1 \to \tilde{l}\nu_l b, \tilde{t}_1 \to \tilde{\nu}_l l b$

- FCNC decay mode is possible $\tilde{t}_1 \to c\tilde{\chi}_1^0$

- stop could even hadronize for $\tau_{\tilde{t}_1} \gg 1/\Lambda_{QCD}$

Monojet signature

- charms are too soft to be detected, thus the stops are invisible
- Carena et. al. considered production of stop pairs in association with one jet
- signature: one hard jet and MET
- we reanalyzed the signature and have taken into account the full SM BG and optimized cuts



Numerical results

- dominant SM background

$$(Z \to \nu\bar{\nu}) + j$$

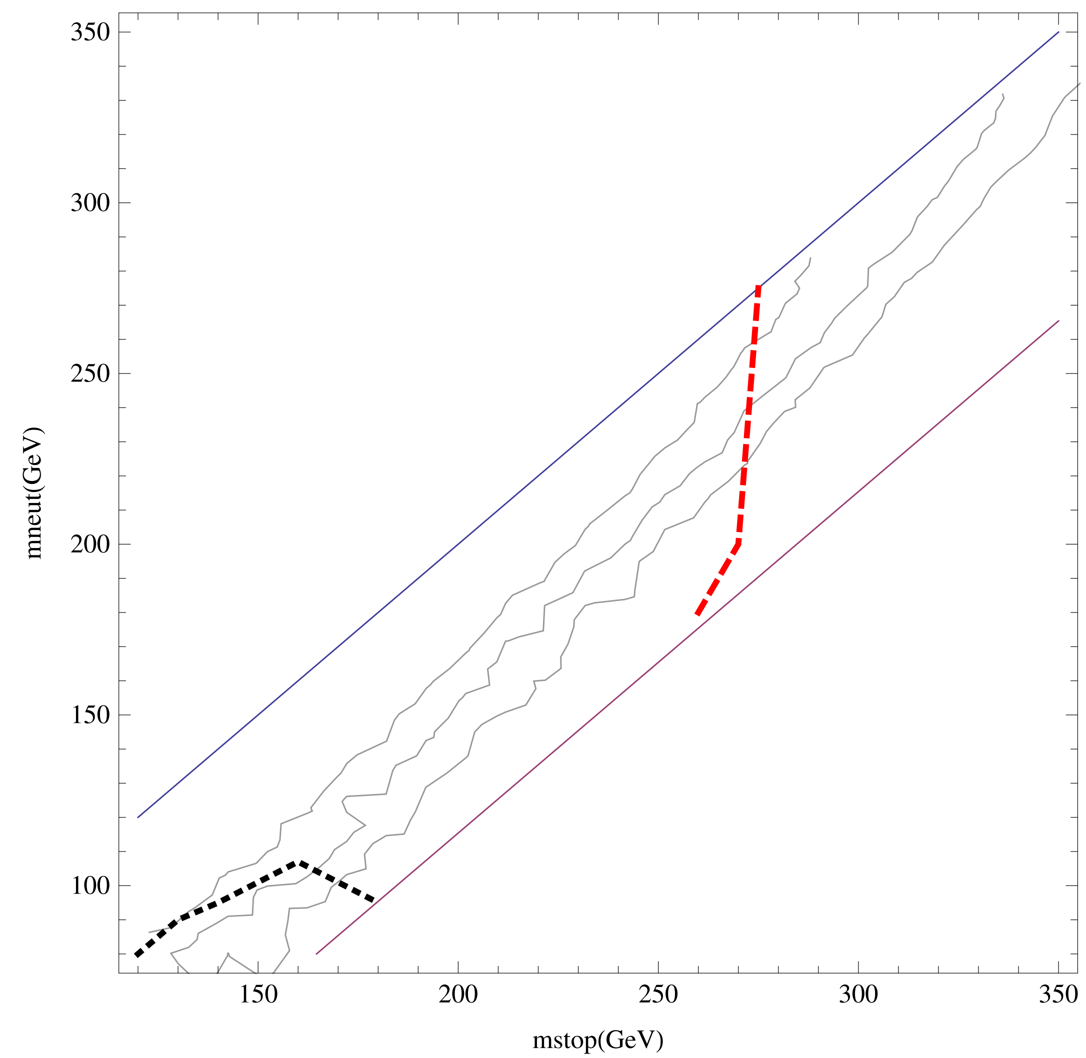
- however can be measured from

$$(Z \to \ell\bar{\ell}) + j$$

- demand a high transverse momentum jet (PT>500 GeV) balanced by MET (MET>500 GeV)

- remaining SM background can be suppressed by lepton veto and veto on second jet

Statistical significance

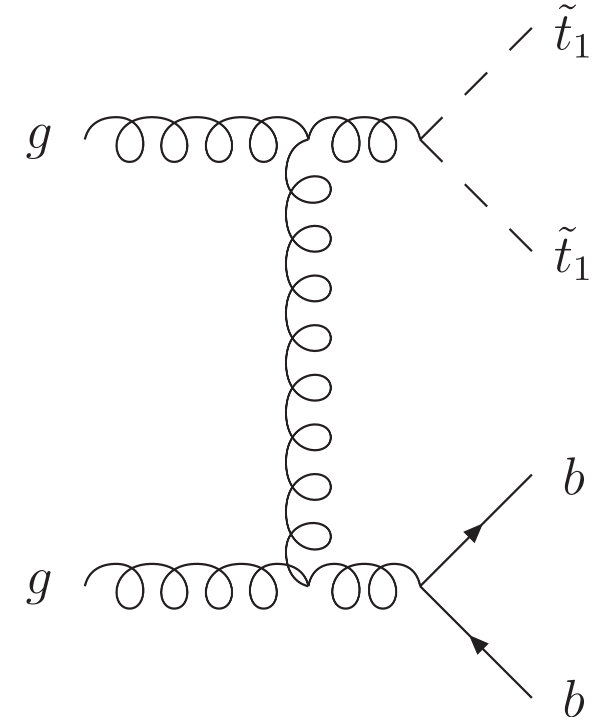


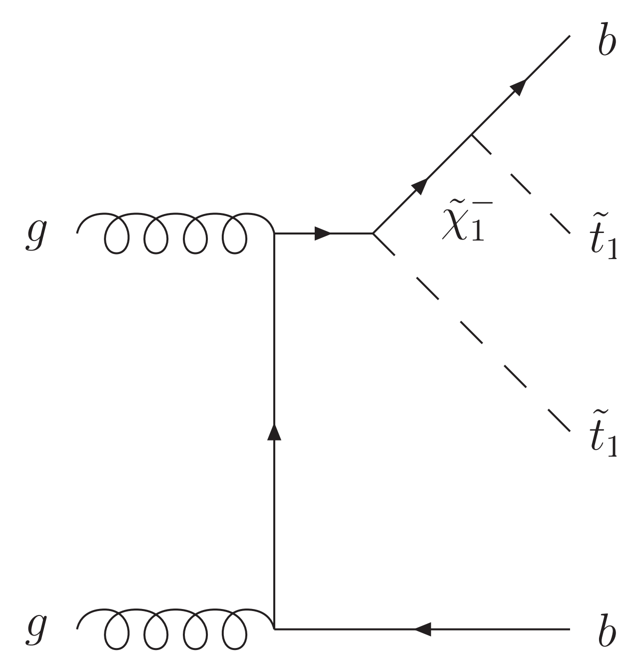
$\mathcal{L} = 100\,\mathrm{fb}^{-1}$ at 14 TeV

Are there alternative processes?

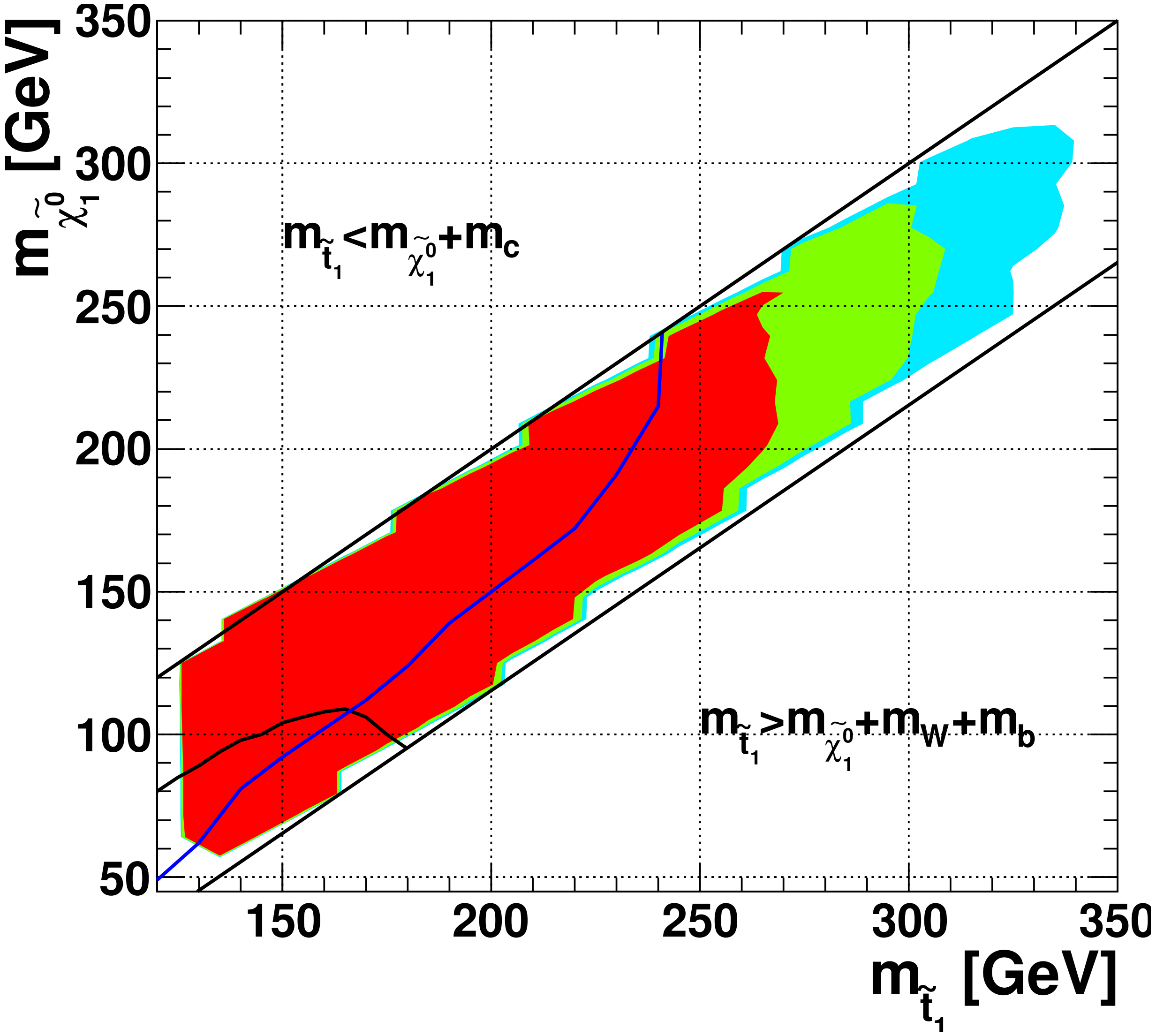
Stop pairs in association with 2 b‘s

- QCD and EW contributions at leading order
- assume $m_{\tilde{\chi}_1^\pm} > m_{\tilde{t}_1}$
- EW contribution is not phase space suppressed compared to QCD contribution
- demand two b-jets (PT>200 GeV, PT>50 GeV) and large MET>200 GeV

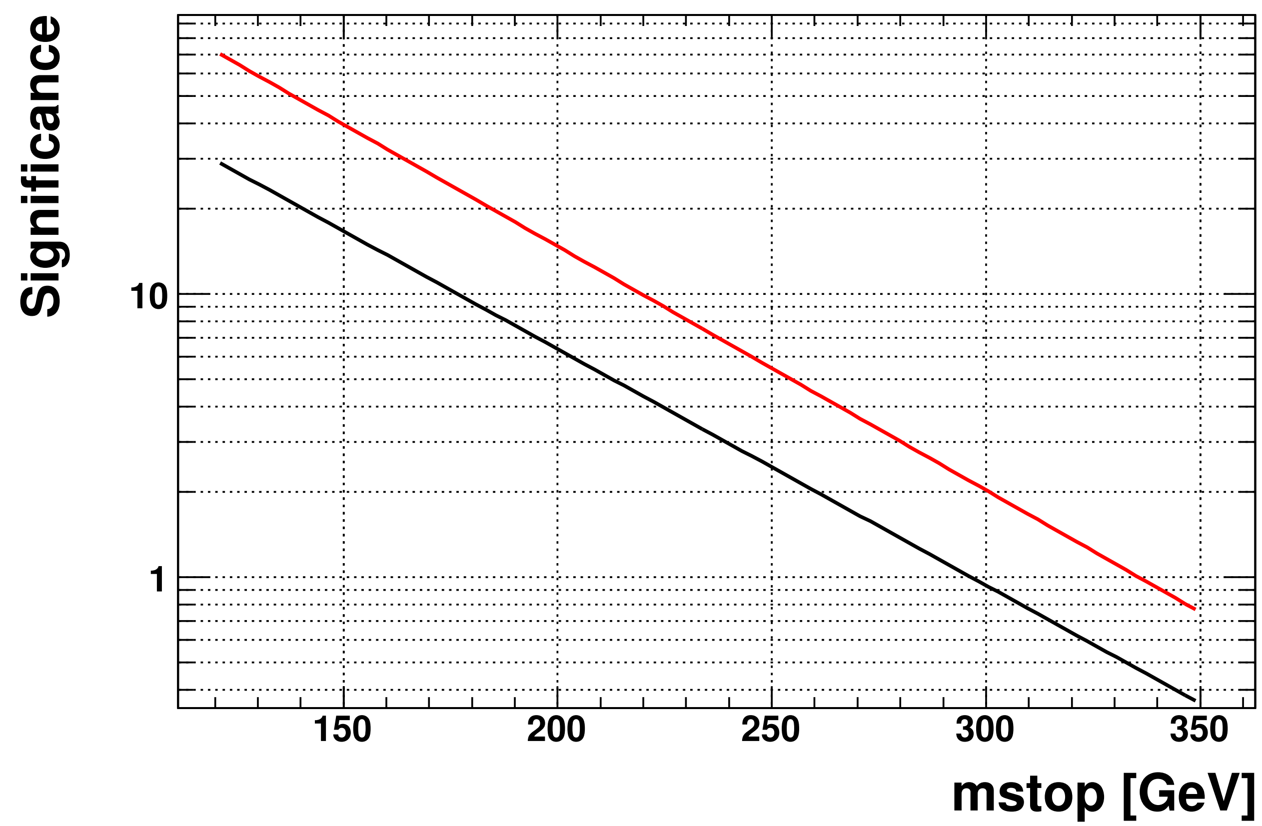




Numerical results



red: 5 sigma
green: 3 sigma
turqoise: 2 sigma



red curve: QCD+EW
black curve: QCD

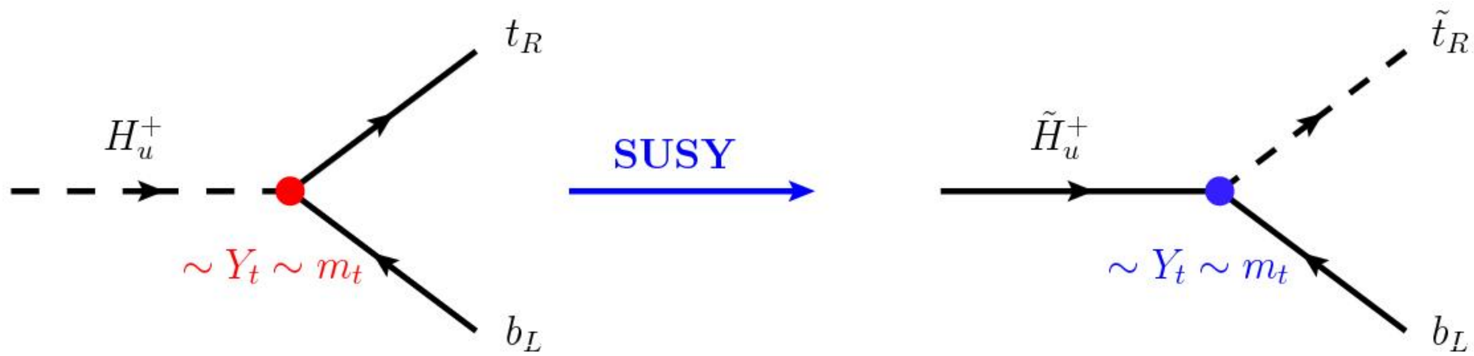
$\mathcal{L} = 100\,\mathrm{fb}^{-1}$ at 14 TeV

Now assume, excess over the SM expectation has been found.

Test for supersymmetry

- we have to find for every SM partner its superpartner
- we have to measure the spin of the particles
- we must test $g_i(V_i, f, f') = \tilde{g}_i(\tilde{V}_i, f, \tilde{f}')$
- we must test the relations from the superpotential

Coupling relations from the superpotential



- strongly interacting particles
- large top Yukawa coupling
- higgsino-like lightest chargino and lightest stop is mostly right-handed
- our signal involves $\tilde{t}_1 - \tilde{\chi}_1^{\pm} - b$ coupling

Signal process

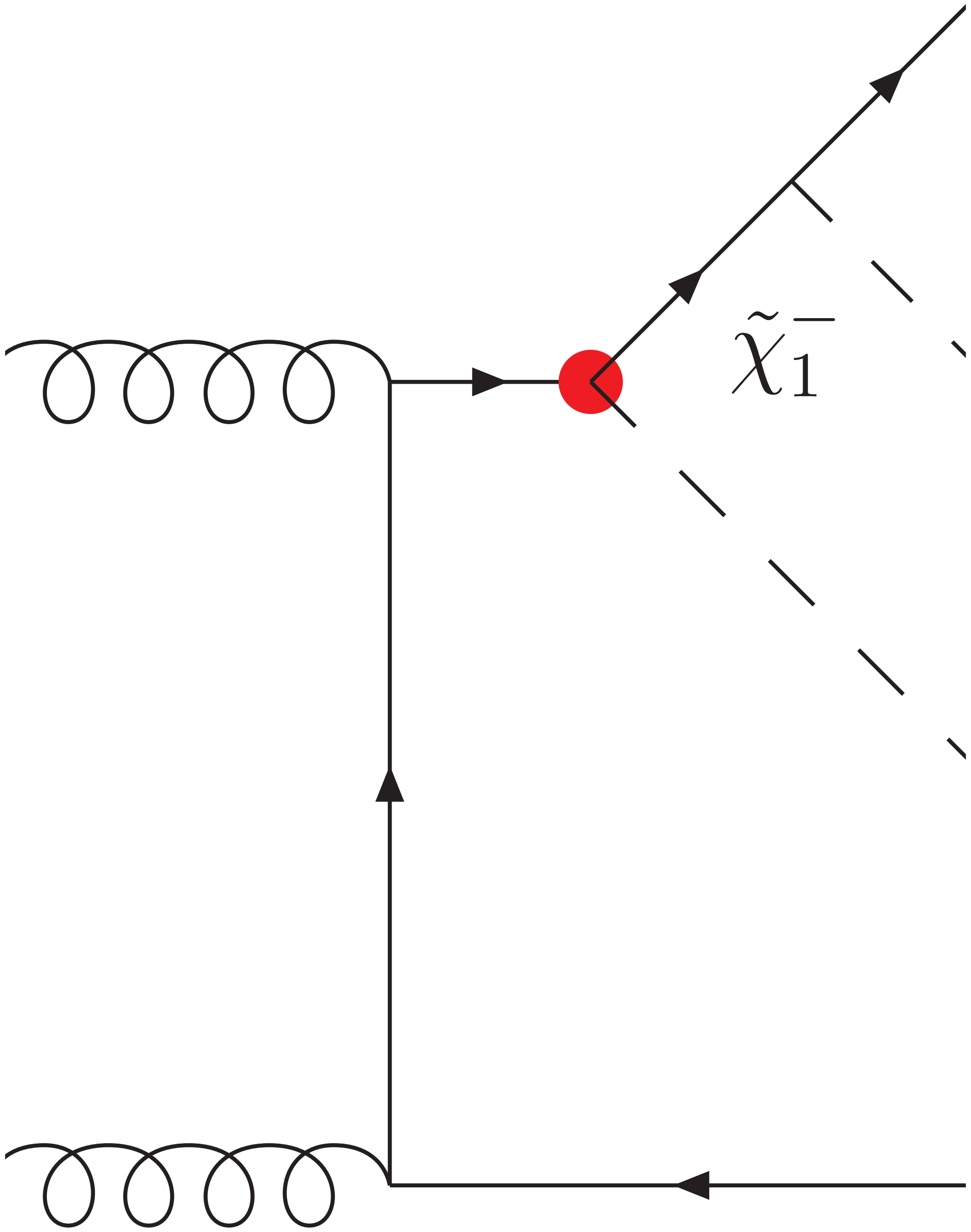
- cross section depends on coupling

$$\tilde{t}_1 - \tilde{\chi}_1^{\pm} - b$$

- it's a 2-3 process for

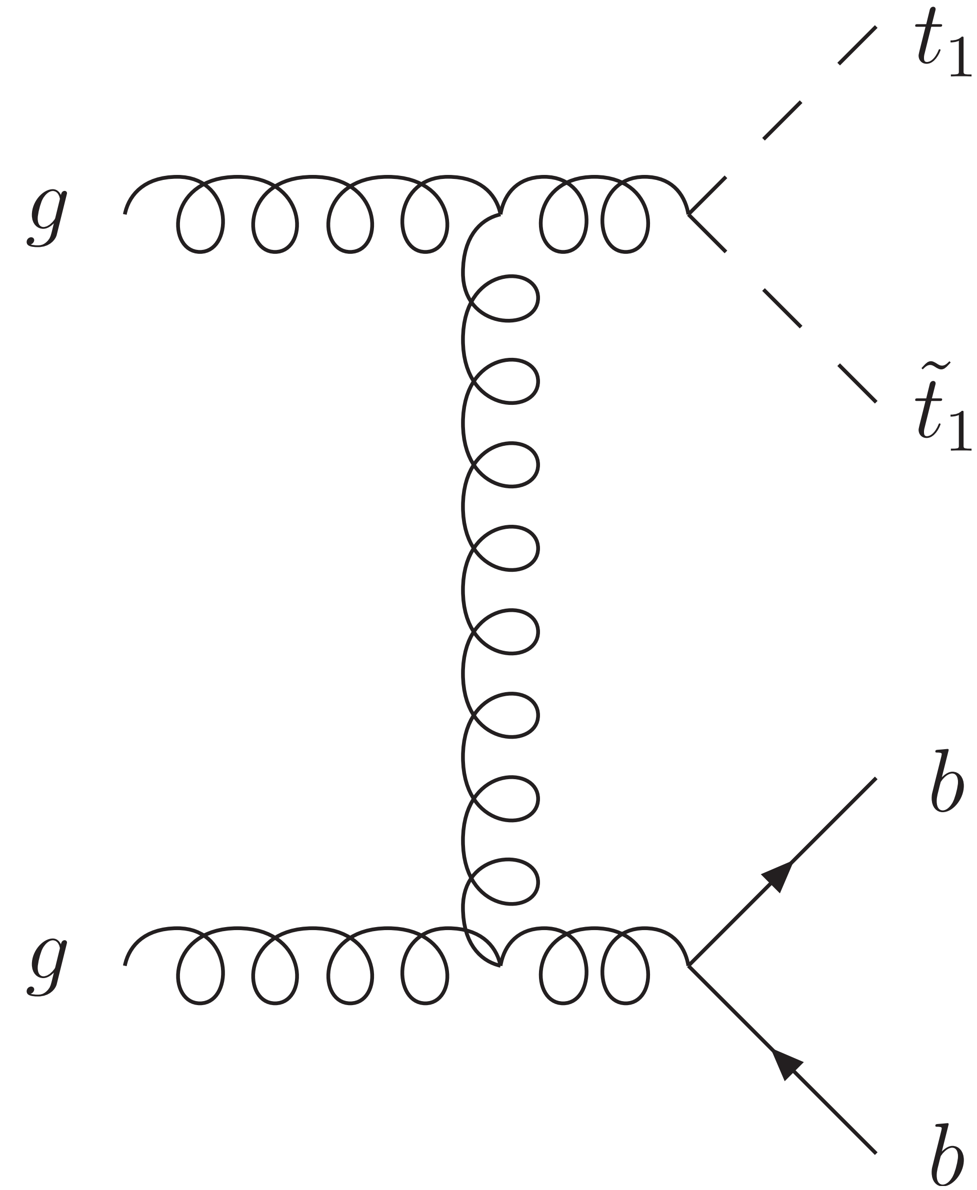
$$m_{\tilde{\chi}_1^{\pm}} > m_{\tilde{t}_1}$$

- by measuring the cross section, we can determine the coupling provided we know the masses



SUSY Background

- the SUSY QCD contribution is background is now
- SUSY background is related to monojet signature
- the monojet process is independent of the superpotential coupling
- to which precision can we reconstruct the coupling?



Coupling reconstruction

- light stop scenario

$$m_{\tilde{\chi}_1^0} = 100\,\mathrm{GeV}$$
$$m_{\tilde{t}_1} = 120\,\mathrm{GeV}$$
$$m_{\tilde{\chi}_1^\pm} = 140\,\mathrm{GeV}$$

- we assume $\mathcal{L} = 100\,\mathrm{fb}^{-1}$ at 14 TeV
- we demand $\Delta\eta(b\bar{b}) = 2$
- errors are added in quadrature

error	$\Delta\sigma/\sigma$	$\Delta\lambda/\lambda$
lumi	3 %	1,5 %
PDF	7,3 %	3,7 %
NLO	24 %	12 %
Δm	22,7 %	11,4 %
statistics	7 %	3,5 %
∑		17,4 %

Summary

- direct stop pair production is difficult to probe at hadron colliders
- we considered monojets and 2 b - jets & MET
- stop masses up to a few hundred GeV can be probed
- we can test the superpotential coupling relations

Cutflow

$m_{\tilde{t}_1} = 220\,\mathrm{GeV},\ \Delta\mathrm{m} = 210\,\mathrm{GeV}$

With 100 fb^{-1} at $\sqrt{s} = 14$ TeV

cut	$Z+j$	$W+j$	$W_\tau + j$	$t\bar{t}$	signal	S/B	Signif.
$p_T(j_1)$ cut	27 619	69 802	35 137	2206070	17 797	0.008	0.08
$\not{E}_T$ cut	22 798	20 738	16 835	63 320	13 350	0.108	1.94
veto on e, μ	22 284	6 363	11 978	23 416	12 810	0.200	4.68
veto on taus	22 221	6 274	9 031	22 848	12 727	0.21	4.96
veto on b–jets	21 295	5 968	8 617	11 424	11 064	0.23	6.94
jet veto	15 415	3 702	5 128	1 408	5 848	0.23	8.17

- we assume that $Z(\to \nu\nu) + j$ can be measured from $Z(\to \ell^+\ell^-) + j \Rightarrow$ larger statistical error $\Rightarrow$ conservative estimate $\delta B_Z = \sqrt{5.3 B_Z}$
- we assume a systematic error of 10% for each other background channel

Cutflow

$m_{\tilde{t}_1} = 120\,\mathrm{GeV},\ \Delta\mathrm{m} = 20\,\mathrm{GeV}$

cut	Wbb	single t	Zbb	$t\bar{t}$	signal	S/B	$S/\sqrt{B}$
$\not{p}_T > 200\,\mathrm{GeV}, 2b$	6144	10390	33440	179900	23360	0.098	49
$p_T(b_1) > 150\,\mathrm{GeV}$	5765	7824	27720	127200	20760	0.123	51
$p_T(b_2) > 50\,\mathrm{GeV}$	4269	5476	19290	92330	15360	0.127	44
lepton veto	1286	2373	19290	32400	15360	0.278	66
$\#n_{\mathrm{charged}} \geq 10$	1096	2227	15570	32200	15020	0.293	67
$p_T(b_1)/\not{p}_T < 1.6$	881	1485	14970	22030	13700	0.348	69

- for $\mathscr{L} = 100\ fb^{-1}$ at $\sqrt{s} = 14$ TeV
- signal has no parton–level leptons
- we only considered $Z \to \nu\nu$
- $W/Zb\bar{b}$ has less charged hadrons than our signal
- $p_T(b_1) - \not{p}_T$ imbalance larger for SM background