Search for pair produced top squarks into a charm quark and the lightest neutralinos in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector at the LHC

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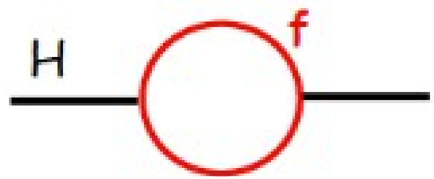
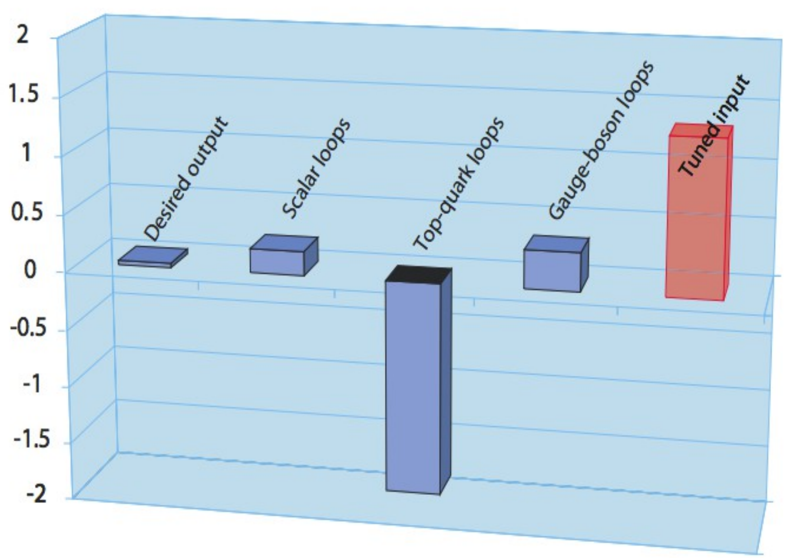
Motivation (1)

- Particles in the Standard Model (SM) have masses around the EW scale.
  - No new particles between M_W (~10^2 GeV) and M_P (~10^{18} GeV)?
- Higgs mass receives quantum corrections from every particle to which it couples.
  - Corrections can be up to 30 orders of magnitude larger than M_H (if Λ_{UV} ~ M_P)



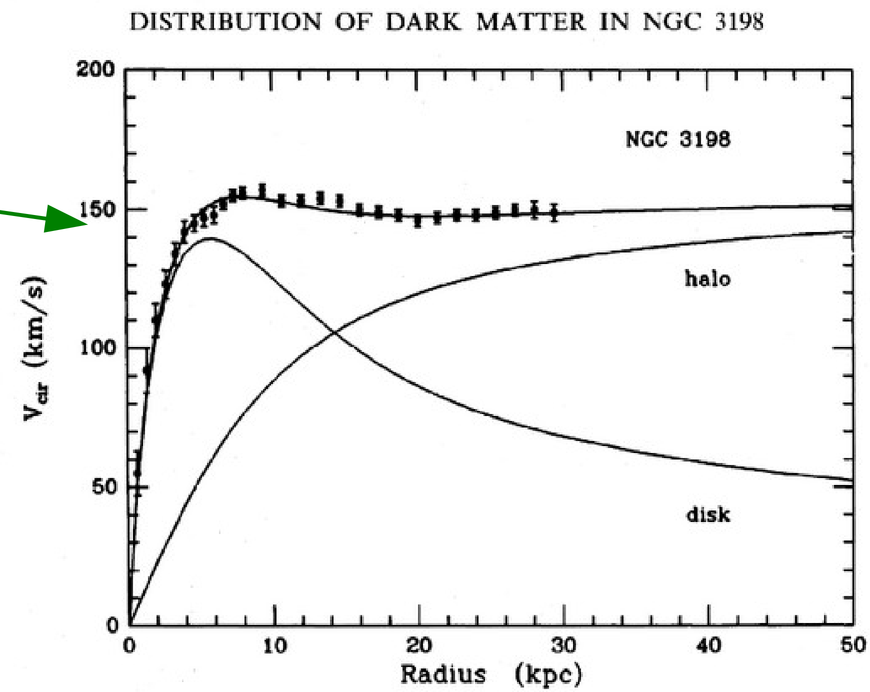
$$\Delta m_H^2 = -\frac{|\lambda_f|^2}{8\pi^2}\Lambda_{\mathrm{UV}}^2 + \ldots .$$



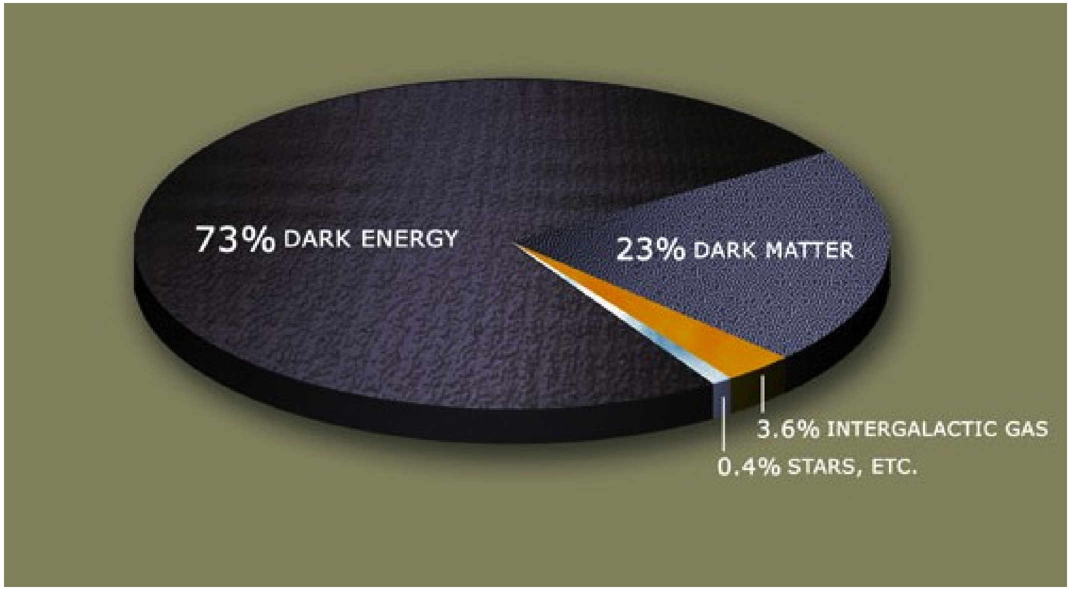
- Already a serious problem at 5 TeV to cancel top, gauge and Higgs loops.
  - Is there a mechanism to cancel them?

Motivation (2)

- Rotation of the stars around the center of the galaxies NOT consistent with the amount of mass observed.



- Gravitational lensing is an indication of Dark Matter (DM) in galaxy clusters.
- Collisions of clusters of galaxies
- Neutrino is NOT a good DM candidate
- What is DM?

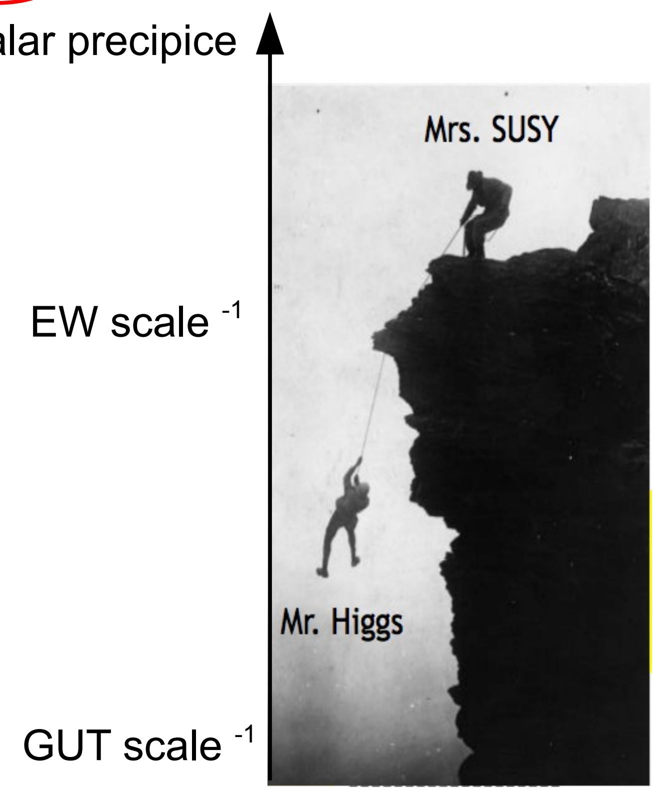


Supersymmetry (SUSY)?

Motivation (3)

- Inclusive SUSY searches point to squarks and gluinos at the level of the TeV.

Inclusive Searches							
MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q},\tilde{g}$ 1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2013-047
MSUGRA/CMSSM	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.2 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-062
MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	any $m(\tilde{q})$	1308.1841
$\tilde{q}\tilde{q}$, $\tilde{q}\to q\tilde{\chi}^0_1$	0	2-6 jets	Yes	20.3	$\tilde{q}$ 740 GeV	$m(\tilde{\chi}^0_1)$=0 GeV	ATLAS-CONF-2013-047
$\tilde{g}\tilde{g}$, $\tilde{g}\to q\bar{q}\tilde{\chi}^0_1$	0	2-6 jets	Yes	20.3	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}^0_1)$=0 GeV	ATLAS-CONF-2013-047
$\tilde{g}\tilde{g}$, $\tilde{g}\to qq\tilde{\chi}^{\pm}_1\to qqW^{\pm}\tilde{\chi}^0_1$	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.18 TeV	$m(\tilde{\chi}^0_1)$<200 GeV, $m(\tilde{\chi}^{\pm})=0.5(m(\tilde{\chi}^0_1)+m(\tilde{g}))$	ATLAS-CONF-2013-062
$\tilde{g}\tilde{g}$, $\tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}^0_1$	2 e,μ	0-3 jets	-	20.3	$\tilde{g}$ 1.12 TeV	$m(\tilde{\chi}^0_1)$=0 GeV	ATLAS-CONF-2013-089

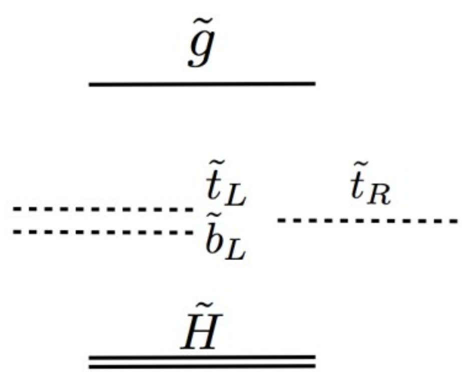


- Cancellation of the top loop correction to the Higgs mass needs a light third generation squarks.

$$\frac{m_H^2}{2} = -|\mu|^2 + \ldots + \delta m_H^2$$

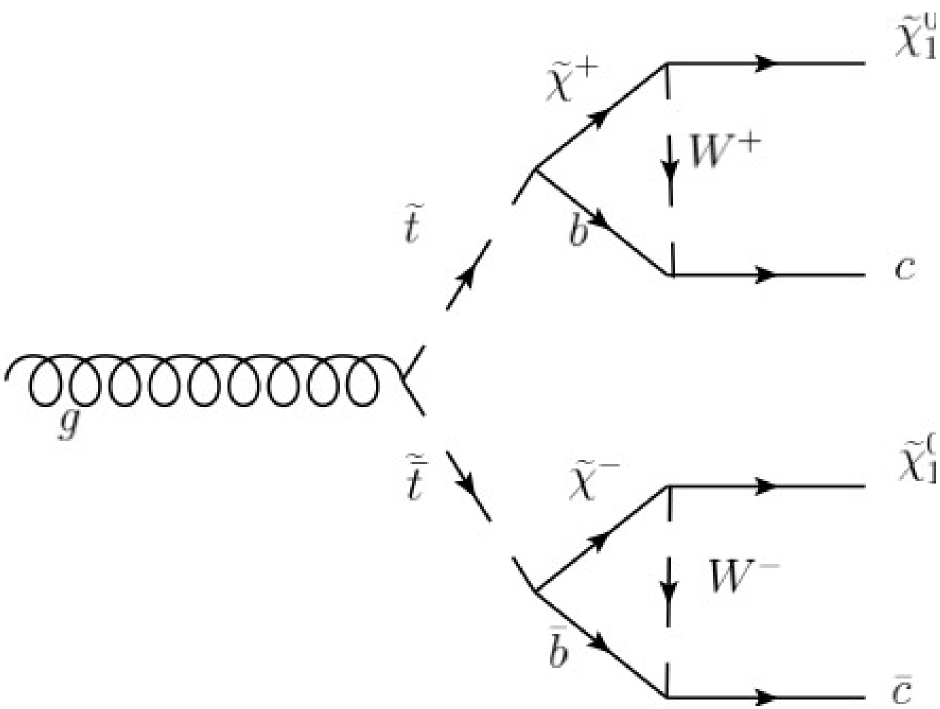
$$\delta m_H^2\Big|_{stop} \cong -\frac{3y_t^2}{8\pi^2}\left(m_{Q_3}^2 + m_{U_3}^2 + |A_t|^2\right)\ln\left(\frac{\Lambda}{TeV}\right)$$

$$\delta m_H^2\Big|_{gluino} \cong -\frac{2y_t^2}{\pi^2}\left(\frac{\alpha_s}{\pi}\right)|M_3|^2\ln^2\left(\frac{\Lambda}{TeV}\right)$$



Introduction

- In scenarios with very heavy scalar quarks and gluinos, all the interest is now in searches for light third generation quarks.
- When $\Delta m = m_{\tilde{t}} - m_{\tilde{\chi}_1^0} < m_b + m_W$, the stop decay into a charm quark and the lightest supersymmetric particle, $\tilde{t} \to c + \tilde{\chi}_1^0$, may be de dominant decay process.



- For small Δm, the transverse momenta of the c-jets is too low to be reconstructed. A monojet analysis is used.
- For moderate Δm the charm jets receive a large enough boost to be detected. Charm tagging is used.

Event selection

- Two different selections depending on Δm.
  - Monojet-like selection: assumes that the two charm jets can be lost. Makes use of the presence of initial-state radiation jets to identify signal events.
  - Charm-tagged selection: more than three jets are required. It makes use of charm tagging to enhance the SUSY signal.

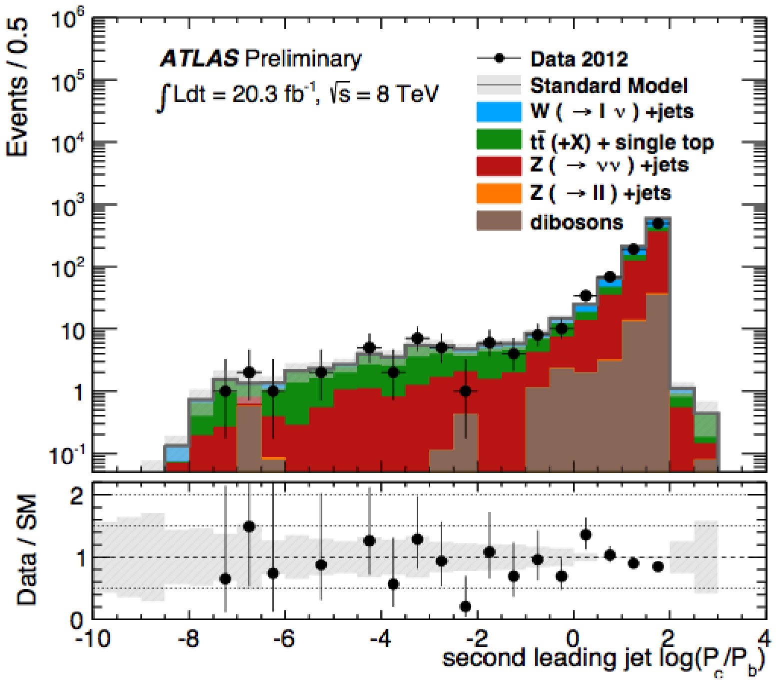
Selection criteria	
Monojet-like selection M1	**Charm-tagged selection C1**
Primary vertex, jet quality requirements and lepton vetoes	Primary vertex, jet quality requirements and lepton vetoes
At most three jets with $p_T > 30$ GeV and $\lvert\eta\rvert < 2.8$ $\Delta\phi(\text{jet}, p_T^{\text{miss}}) > 0.4$	At least three jets with $p_T > 30$ GeV and $\lvert\eta\rvert < 2.5$ (in addition to the leading jet) *b-veto* for second and third jet *medium* *c*-tag for fourth jet $\Delta\phi(\text{jet}, p_T^{\text{miss}}) > 0.4$
minimum leading jet p_T (GeV) 280	270
minimum E_T^{miss} (GeV) 220	410

Charm tagging

- Jets are identified as originating from the hadronization of a charm quark via a dedicated algorithm using multivariate techniques.

- The algorithm provides three weights, one for light-flavor quarks and gluon jets, one for charm jets and one for b-jets.

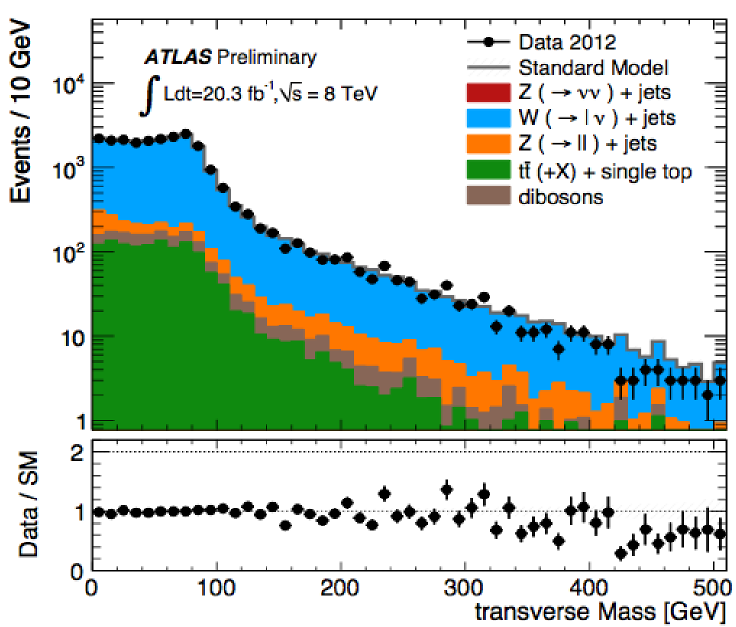
- These weights allow to compute the anti-b, $\log(P_c/P_b)$, and the anti-u, $\log(P_c/P_u)$, discriminators.



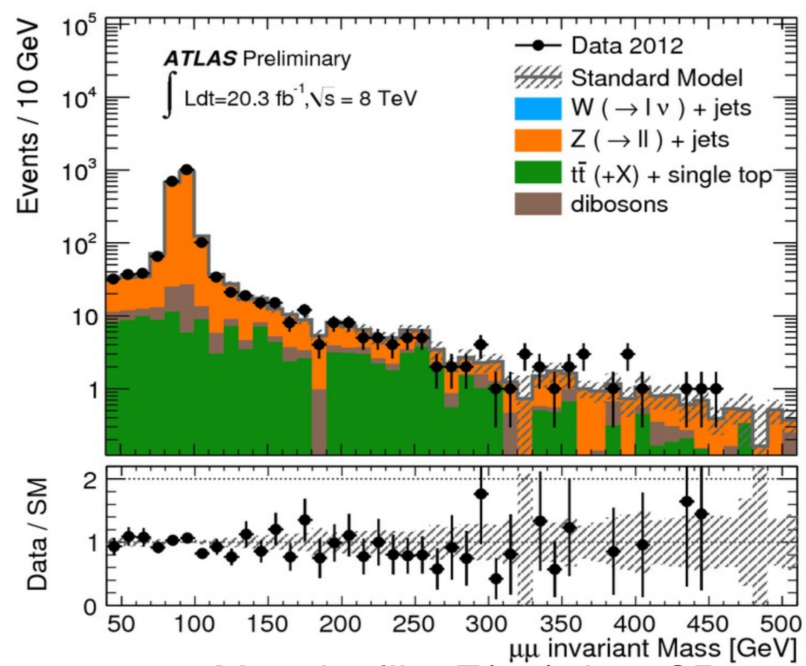
	c-tag eff.	b-rejection	light-rejection	τ-rejection
Medium	20%	5	140	10
Loose (as b-veto)	95%	2	-	-

Background estimation (1)

- Electro-weak background
  - The production of Z and W bosons in association with jets is the main source of background: 94% for monojet-like and 63% for charm-tagged analyses.
  - Normalized with data-driven scale factors retrieved in W/Z+jets control samples defined separately to normalize the different background processes.



Monojet-like W(μν)+jets CR



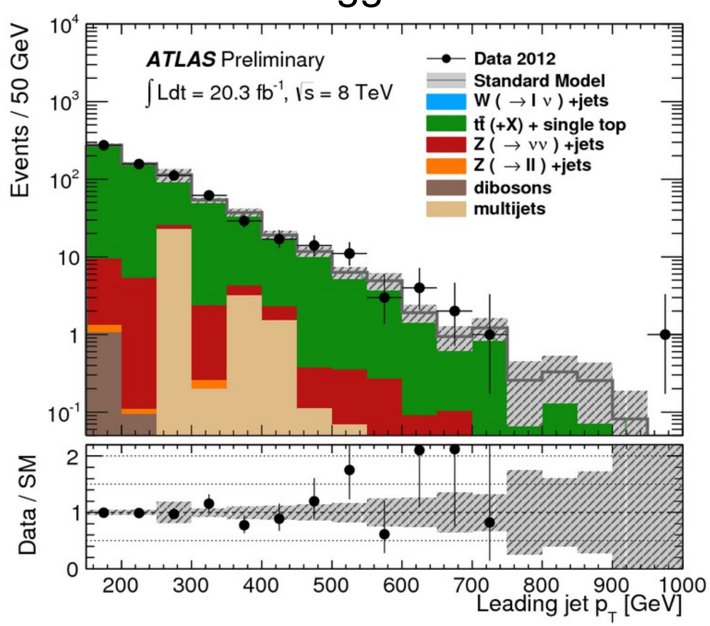
Monojet-like Z(μμ)+jets CR

Background estimation (2)

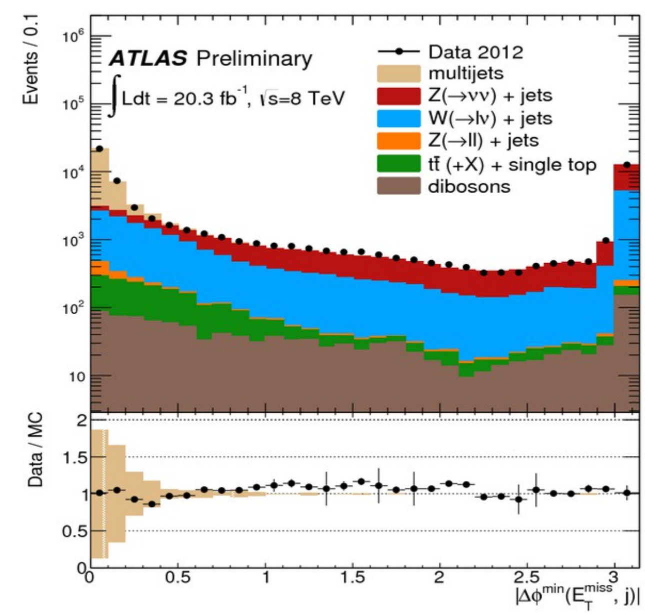
- Top background
  - In the charm tagged analysis is estimated in a separate control region in which b-veto criterion is inverted. It's contribution to the total background is 24%
  - In the case of the monojet-like analysis, this process is small (~2%) and is entirely determined from MC.

- Other less important backgrounds are the multijet, the dibosons and the non-collision background.

Charm-tagged ttbar CR



Normalization of multijet background in monojet-like

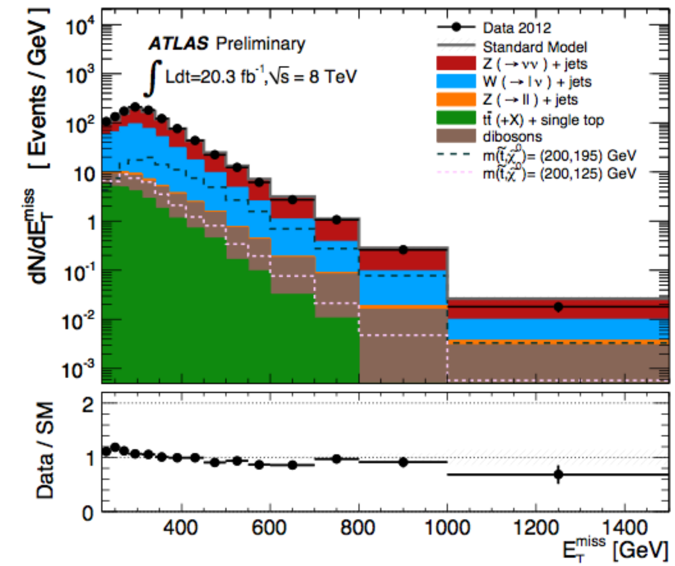


Results

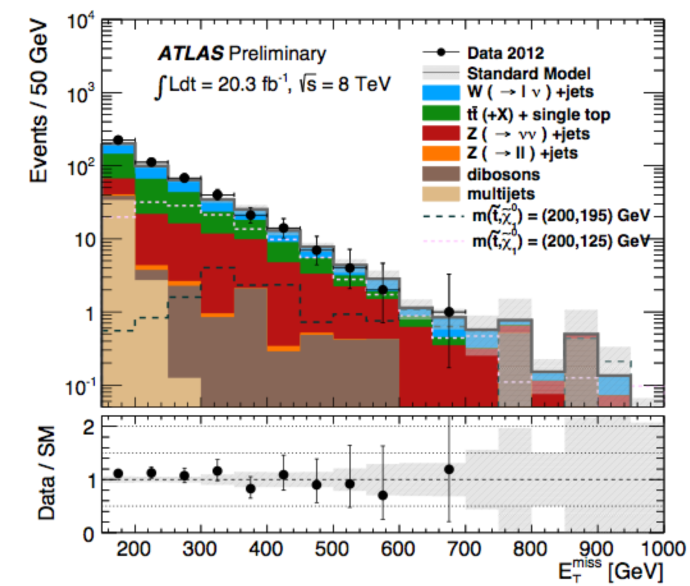
- Different systematic uncertainties are considered in the analysis.
  - Absolute jet Pt and Etmiss energy scale and resolution, pileup corrections, lepton identification efficiencies, the modeling of parton showers and hadronization...
  - Total systematic uncertainty of 3.2% for the monojet-like analysis and a 24% uncertainty for the c-tagged analysis.
- Good agreement is observed between the data and the Standard Model prediction.

Signal Region	M1	C1
Observed events (20.3 fb^{-1})	30793	25
SM prediction	29800 ± 900	29 ± 7

Monojet-like SR

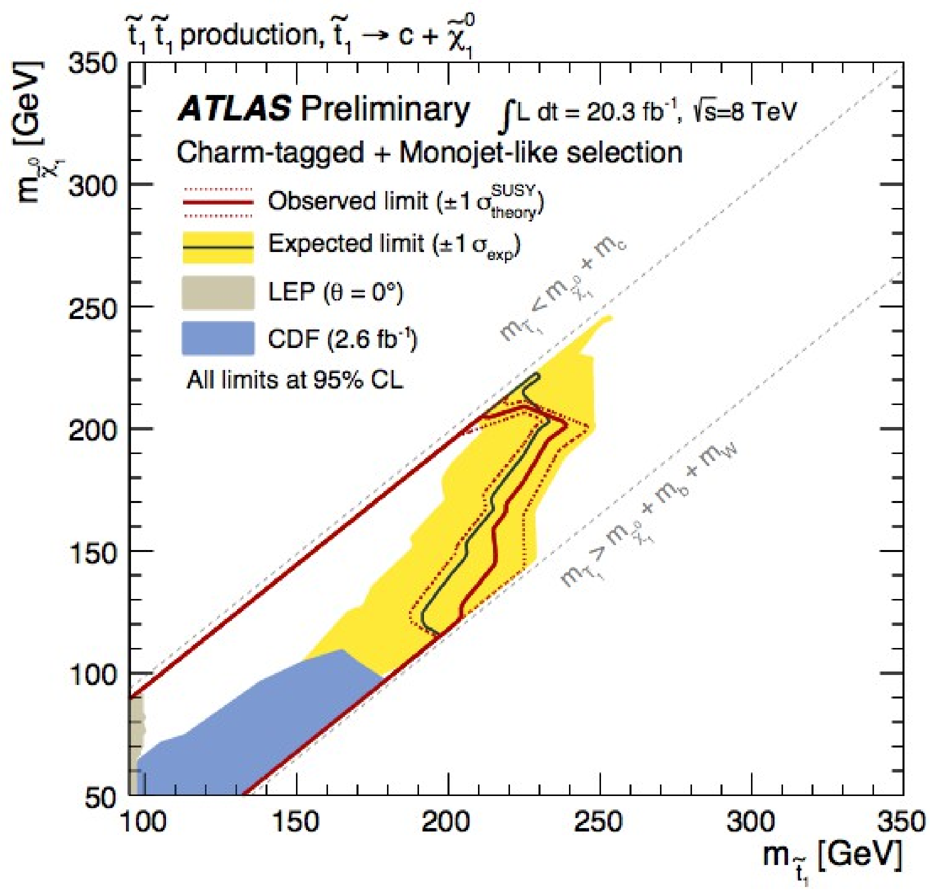


Charm-tagged SR



Exclusion limits

- The results are translated into 95% CL limits on the SUSY stop pair production as a function of the stop mass for different neutralino masses.
- Experimental uncertainties on the signal vary between 2% and 10% in the monojet-like selection, and between 8% and 29% in the charm-tagged selection depending on the stop and neutralino masses.
- Renormalization and factorization scales, PDF uncertainties and variations in α_s, result in a theory uncertainty between 14% and 16%.
- Masses for stop up to 200 GeV are excluded at 95% CL for arbitrary neutralino masses.
- For neutralino masses of about 200 GeV, stop masses below 230 GeV are excluded at 95% CL.

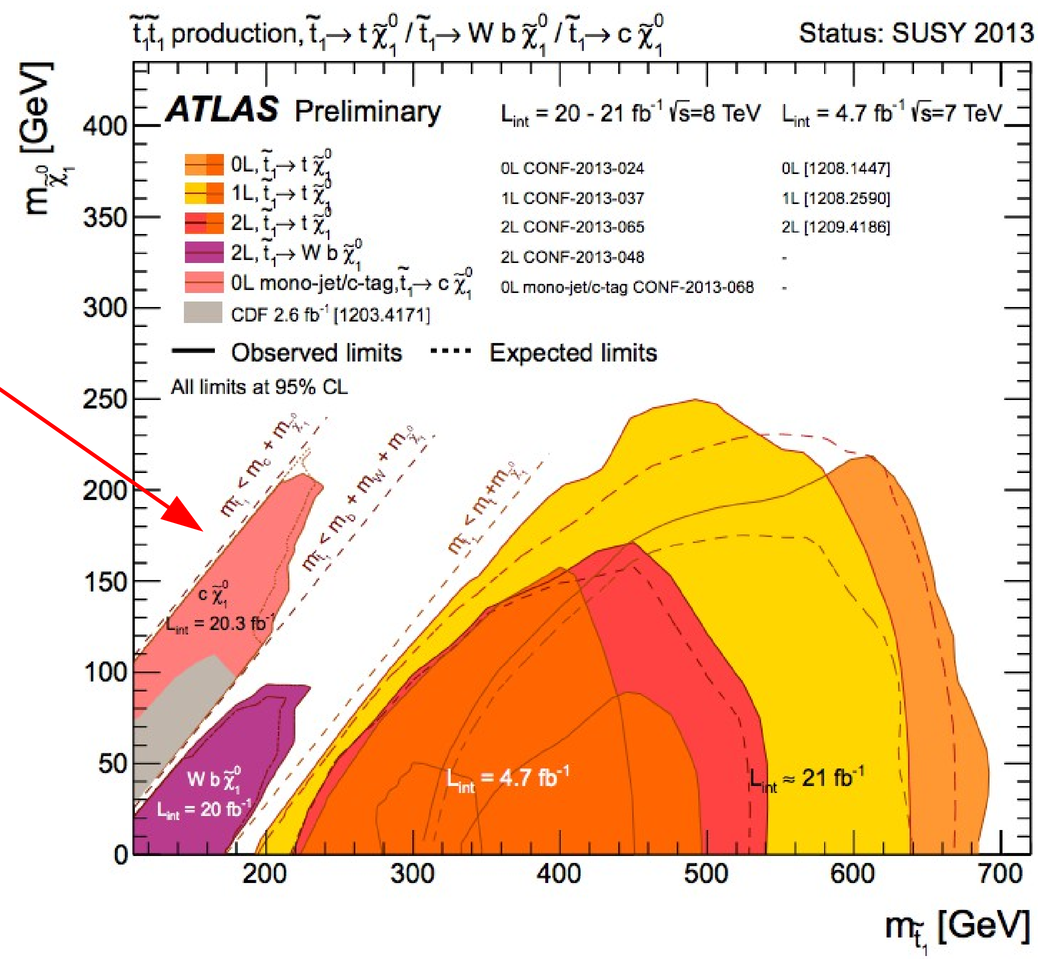


Summary

- First LHC search for a stop decaying to charm neutralino, yielding a stop mass limit of 230 GeV for $m(\chi_1^0) = 200$ GeV.

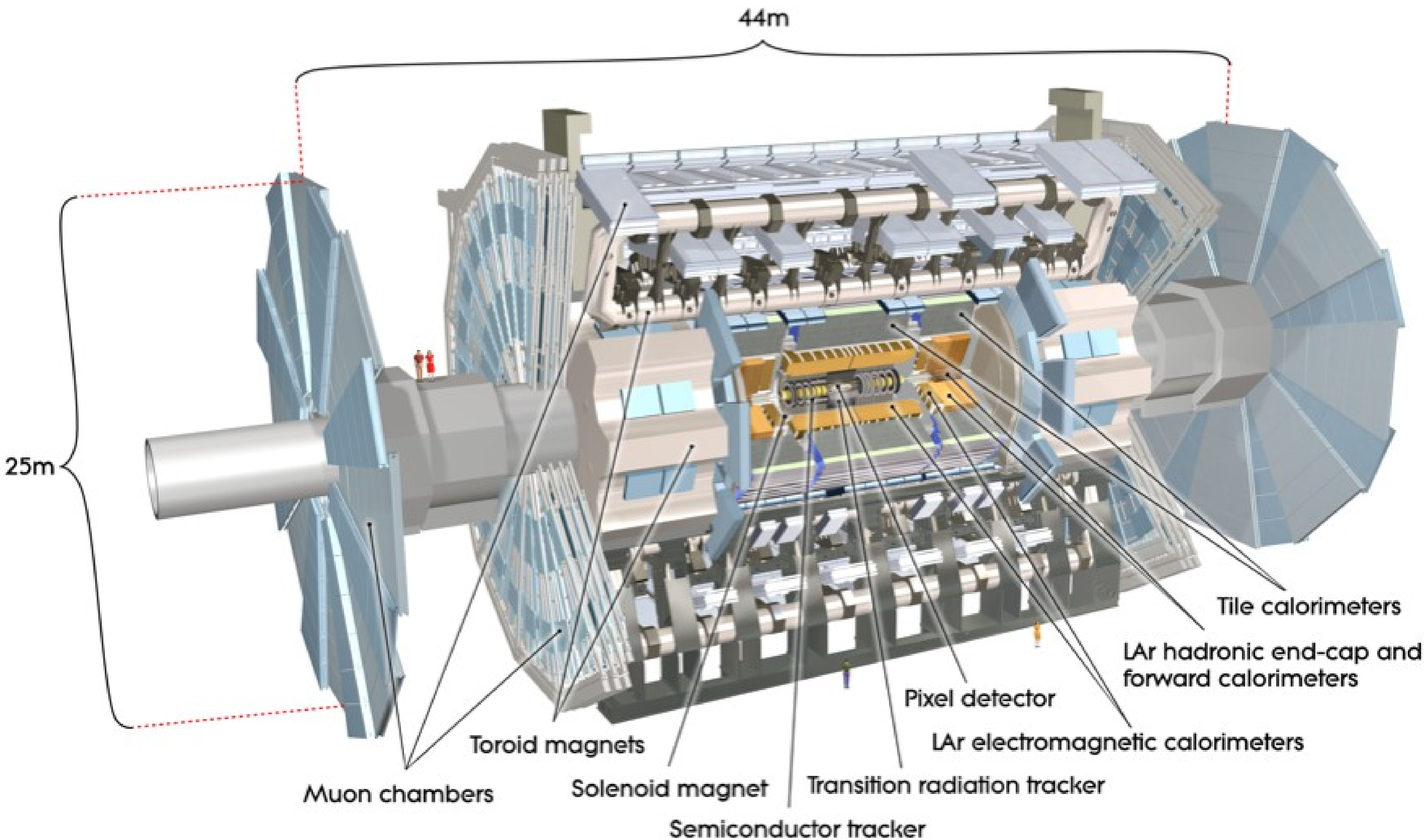
- This analysis excluded an important region with light stops.

- The search for stop quarks continues in ATLAS



Backup slides

The ATLAS detector



Charm tagging

- Uses the primary vertex position or the azimuthal and polar directions of the b-hadron flight axis.

- The algorithm used for charm tag the jets is a combination of two simpler algorithms using a neural network:
  - **IP3D**: uses the impact parameter information to perform a two dimensional log-likelihood ratio using probability density functions for light and b-jets.
  - **JetFitter**: uses the secondary vertex information to fit tracks using the decay topologies of b- and c-hadrons in the jet

- This algorithm provides three weights, one for light-flavor quarks and gluon jets, one for charm jets and one for b-jets.

- The combination of these weights provide the discriminants that define the different c-tagging operating points.