Latest results from SUSY searches at the LHC: where do we stand?

Jad Marrouche

Imperial College London

Searches for SUSY at the LHC: 2010 - 2011

Theoretical Motivations are well known
- I will not repeat them here

Experimental Motivations are also well known
- Potentially rich phenomenology of new particle spectra!

Experimental search strategy for 2010 and 2011
- Develop inclusive topology searches
  - Try to keep signal acceptance the same across all searches

Zero lepton	Single lepton	Dilepton: Opposite Sign	Dilepton: Same Sign	Multi leptons	2-photons	Photon + Lepton

- Go after "low hanging fruit"
  - GUT scale models like CMSSM theoretically and experimentally favoured (m0, m12, A0, tanB) despite the restricted phenomenology
  - Use SPS benchmark points for guidance

- **Experimental Signatures: Jets + missing energy**

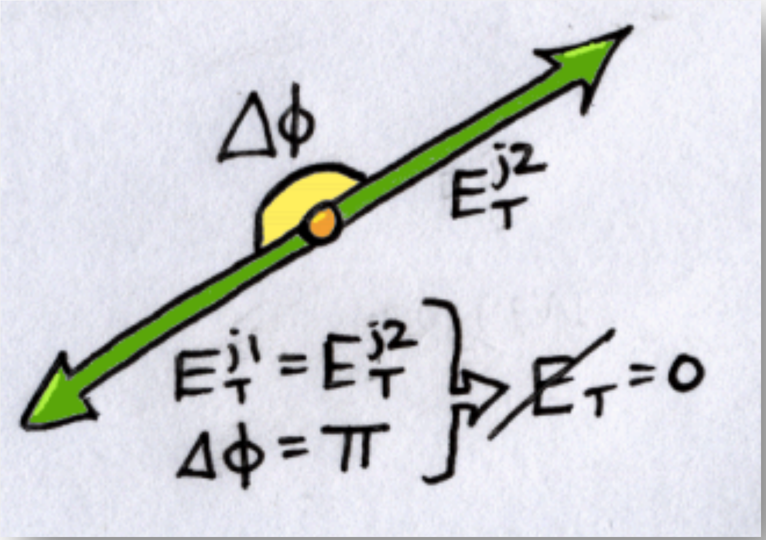
alphaT: The pioneering SUSY search of the LHC

Target the 0-lepton final state
- Highest branching ratios hence largest signal acceptance for this signature

Design a search around the AlphaT variable
- Robustly protects against missing energy arising from mis-measurement of jets from QCD multi-jet events
- Optimised for discovery in early stages of LHC operation

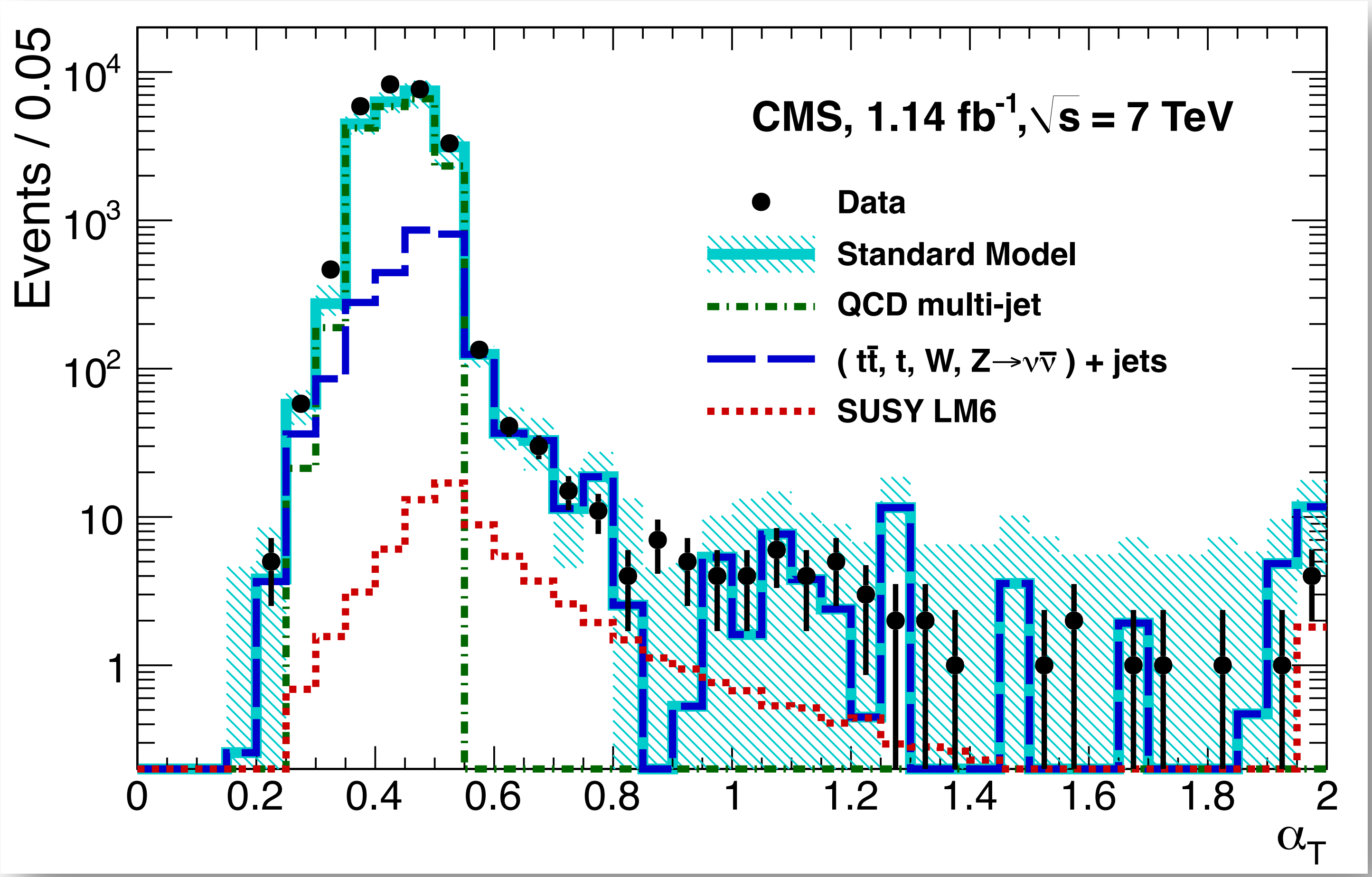
Be as inclusive as possible: **keep thresholds low by calculating AlphaT in the trigger**

$$\alpha_T = \underbrace{\frac{E_T^{jet2}}{M_T}}_{\text{di-jet}} = \underbrace{\frac{1}{2} \times \frac{1-(\Delta H_T / H_T)}{\sqrt{1-(H_T^{miss} / H_T)^2}}}_{\text{multi-jet}}$$



alphaT: The pioneering SUSY search of the LHC

Use AlphaT > 0.55 to deal with QCD



alphaT: The pioneering SUSY search of the LHC

Use background estimates from data control samples to estimate contributions from Standard Model sources with "real" missing energy
- W + Jets
- Z(to neutrinos) + Jets
- ttbar + Jets

Define three control samples in data:
- Single muon + jets
- Single photon + jets
- Dimuon + jets

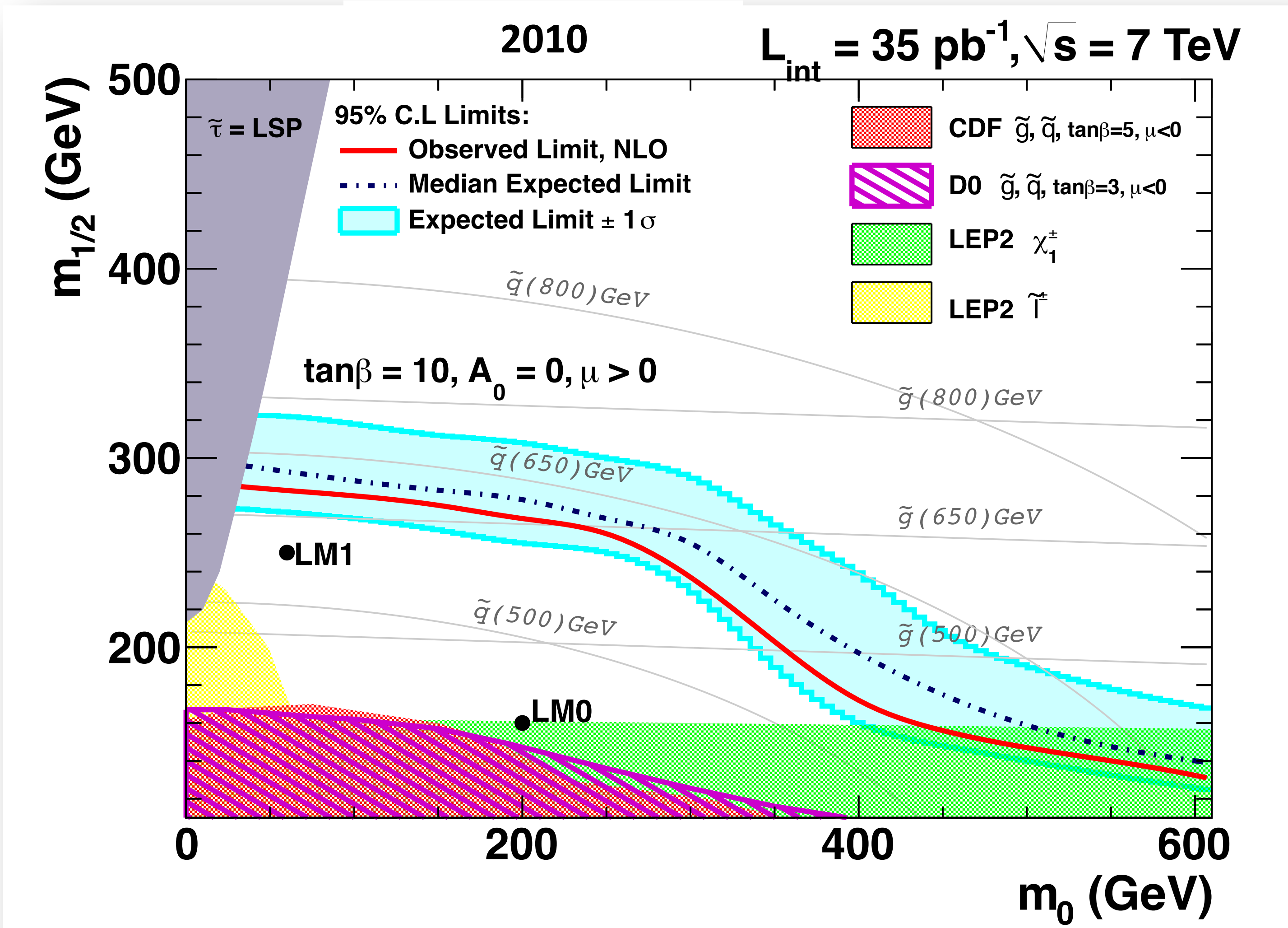
Use Transfer Factor from simulation to predict yields in signal region
- Use comprehensive set of closure tests to estimate systematic uncertainty

$$N_{\mathrm{pred}}^{\mathrm{signal}} = \frac{N_{\mathrm{MC}}^{\mathrm{signal}}}{N_{\mathrm{MC}}^{\mathrm{control}}} \times N_{\mathrm{obs}}^{\mathrm{control}}$$

alphaT: The pioneering SUSY search of the LHC

Compare predictions to data observations:

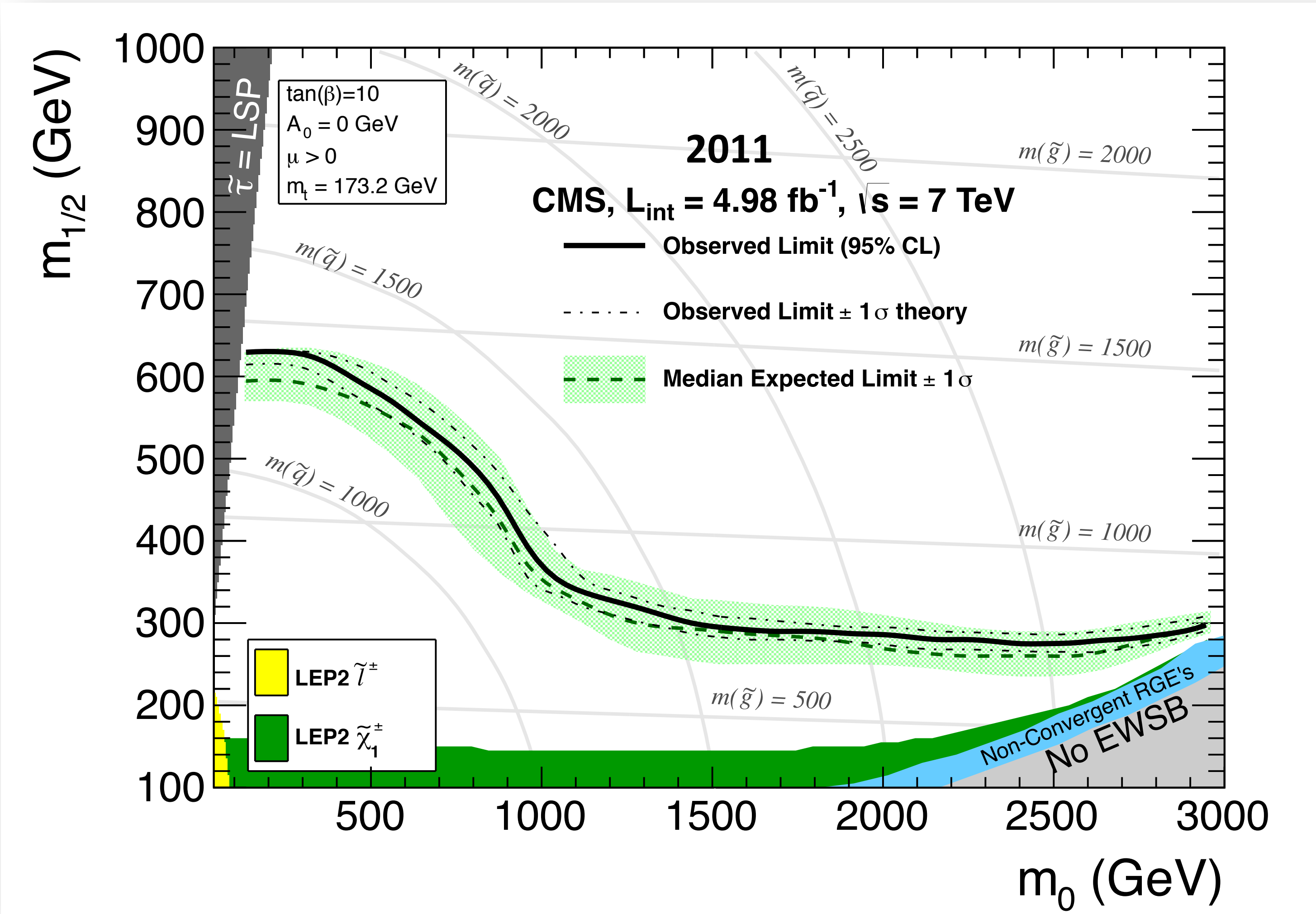
- Best chance to see SUSY since Tevatron!
- Perform interpretation in CMSSM ☹



alphaT: The pioneering SUSY search of the LHC

Compare predictions to data observations:

- Try again with ~150 times more data
- Perform interpretation in CMSSM ☹

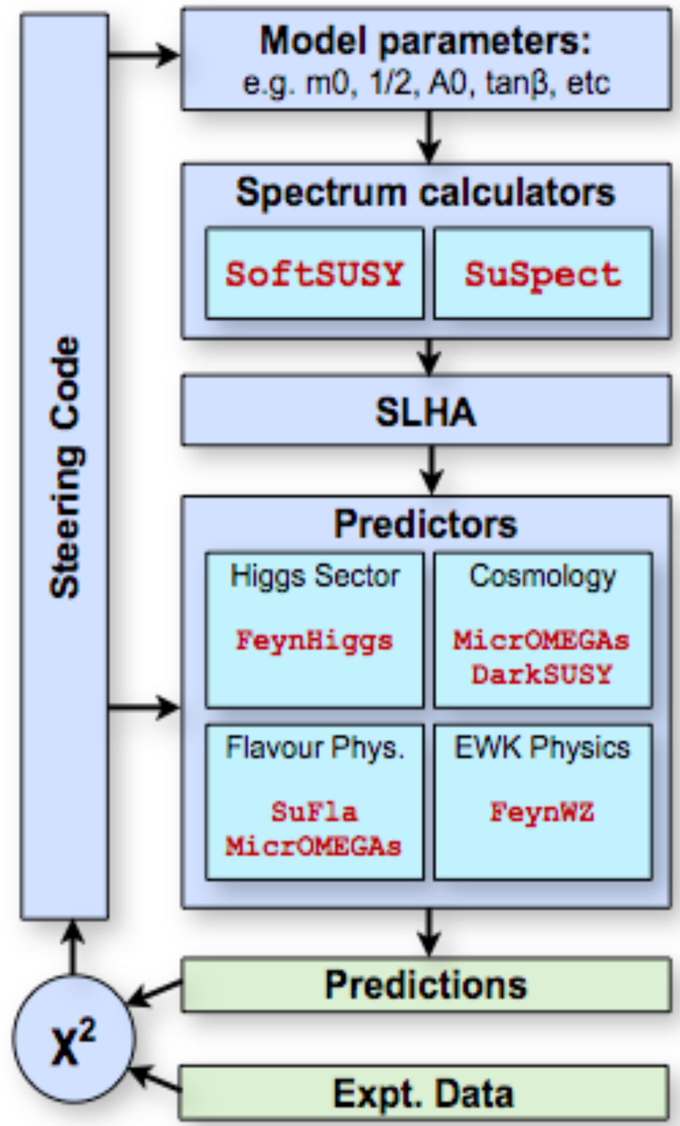


CMSSM Global Fitting: MasterCode

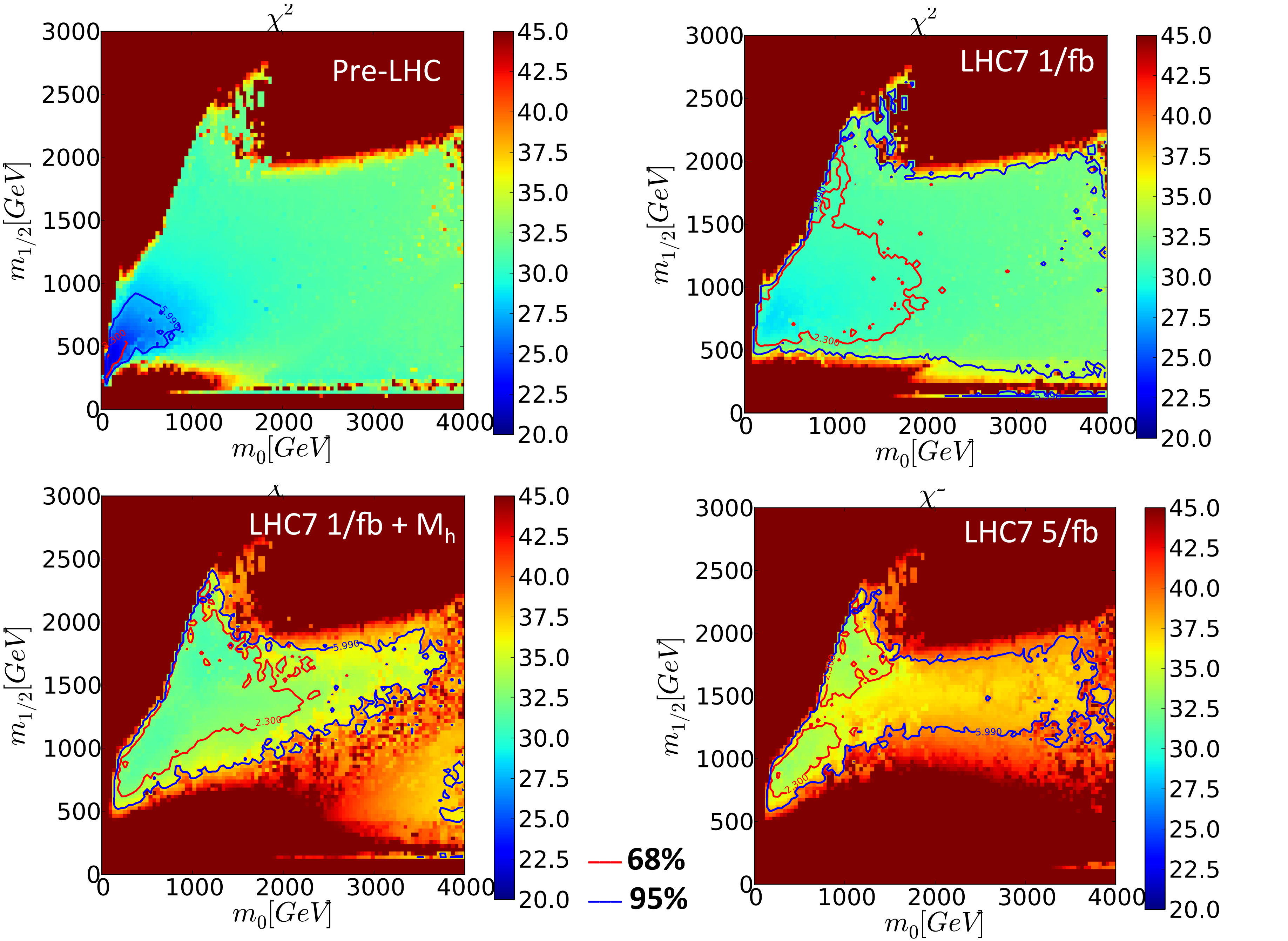
Putting it all together

Recipe:
- Combine measurements
- Compare with predictions
- Constrain the parameters
    - or exclude the model!

Ingredients:
- Accurate set of predictions
- Consistent set of measurements



CMSSM Global Fitting: MasterCode



Now what?

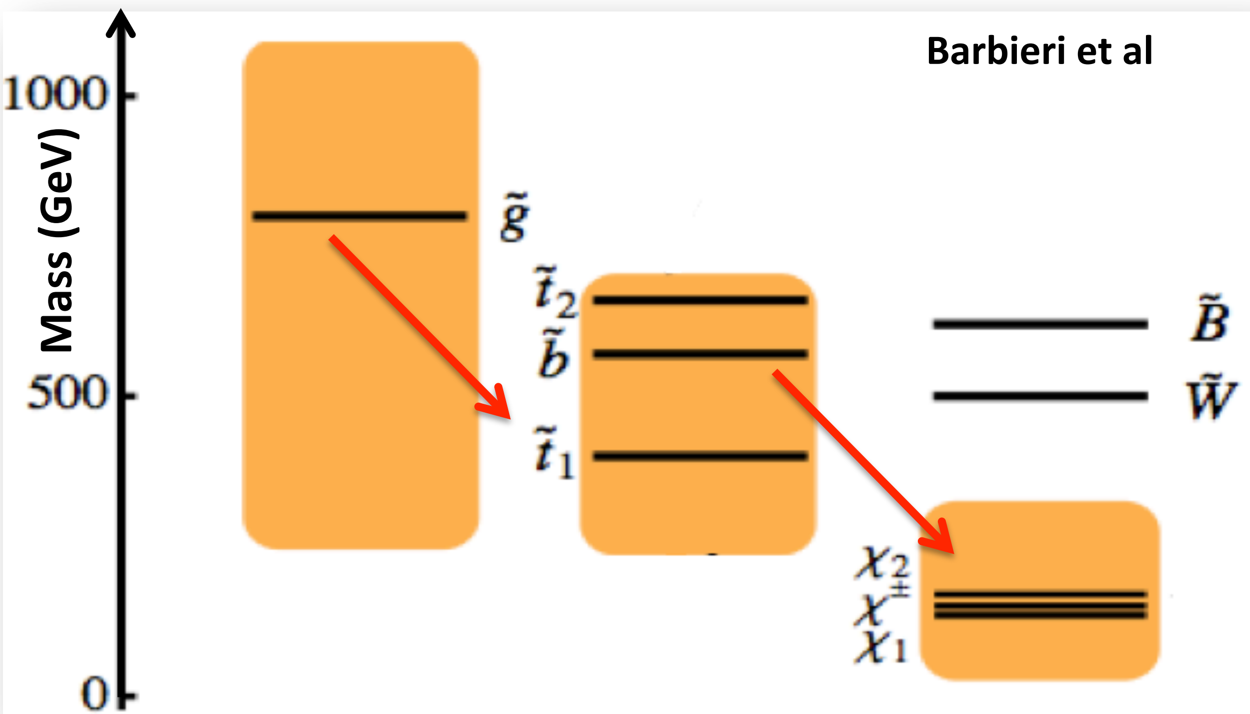
"Natural" SUSY?

Discovery of new boson has further shifted attention towards pieces relevant for SUSY to solve the hierarchy problem.

Require relatively light:
- Gluino
- Third-generation (3G) squarks: stop, sbottom

→ Should be within mass reach of LHC:

Known as "Natural" SUSY:

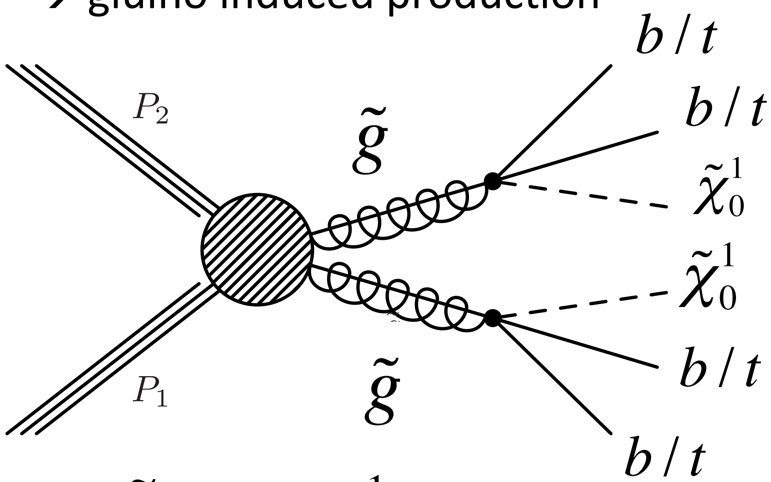


$\tilde{\chi}_0^1$ = Lightest Supersymmetric Particle (LSP) if R-Parity conserved

Searches for SUSY at the LHC: 2012

Initial SUSY search strategies → inclusive, model independent
Now complemented by dedicated searches → especially for "Natural" SUSY signatures:

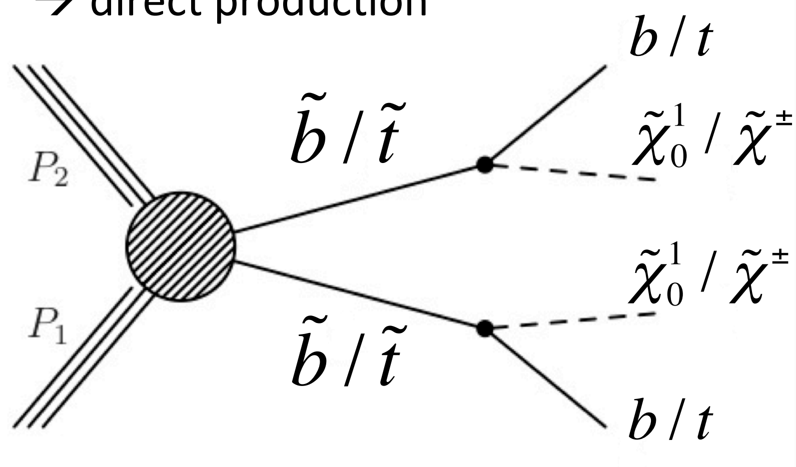
If gluino light enough:
→ gluino induced production



$\tilde{g} \to t\tilde{t} \to tt\tilde{\chi}_0^1$

$\tilde{g} \to b\tilde{b} \to bb\tilde{\chi}_0^1$

If third-generation squarks light enough:
→ direct production



$\tilde{t} \to t\tilde{\chi}_0^1$ $\quad$ $\tilde{t} \to b\tilde{\chi}^\pm \to bW\tilde{\chi}_0^1$

$\tilde{b} \to b\tilde{\chi}_0^1$ $\quad$ $\tilde{b} \to t\tilde{\chi}^\pm \to tW\tilde{\chi}_0^1$

These simplified model spectra (SMS) assume a single production and decay channel and are used to interpret results of the searches. Predominant final state:

- **Jets, especially b-jets, and missing transverse energy (LSP)**
- **Leptonic channels important via decay of the top quarks (and also via chargino)**

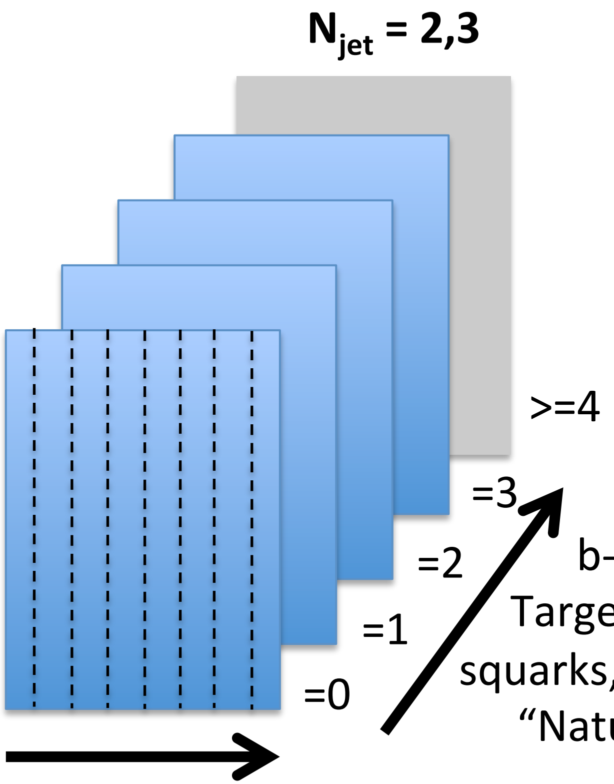
Searches based on 8 TeV data: 0-lepton final states

0-leptons: alphaT

CMS-SUS-12-028_8TeV_11/fb
arXiv:1303.2985

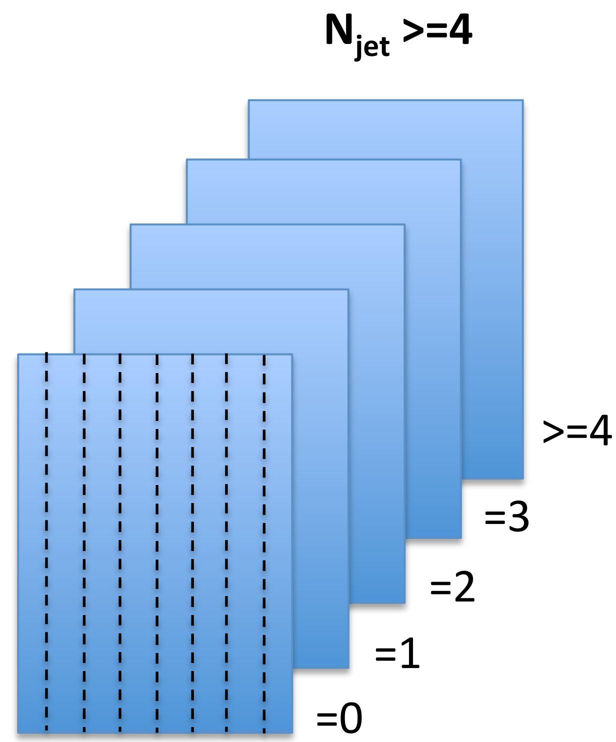
Inclusive search using alphaT kinematic variable

- targets direct and gluino-induced 3G production
- Same philosophy as 2010-2011: alphaT used as "QCD-killer"
- Remaining backgrounds estimated from control regions in data
- Very inclusive search (67 search regions), b-tagging and N_{jet} dimensions added



HT dimension:
Targets compressed and uncompressed spectra

b-tag dimension:
Targets top and bottom squarks, as motivated by e.g. "Natural" SUSY models



Jet multiplicity dimension:
Targets direct and gluino induced SUSY production

0-leptons: alphaT

CMS-SUS-12-028_8TeV_11/fb
arXiv:1303.2985

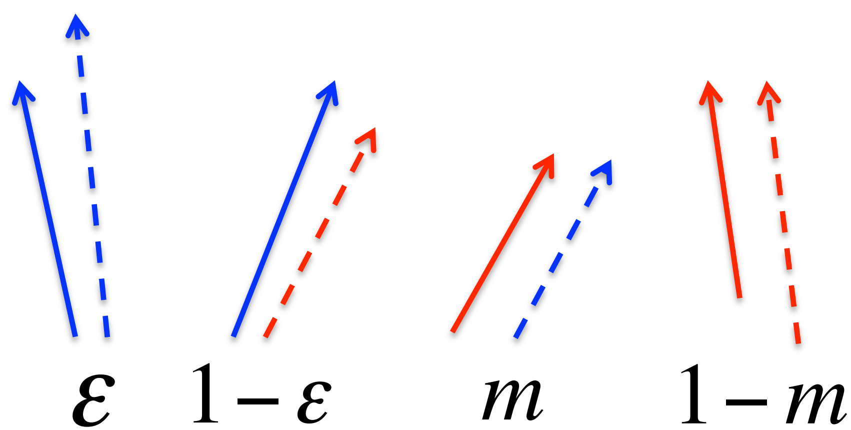
In order to reduce uncertainties on the number of b-tags in our predictions, especially for the 3 and >=4 bins, we use knowledge of the entire event

- Reduces uncertainties by factor 5 for the >=4 b-tag bin!

$$N(n_b) = \sum_{n_{jet}} \sum_{n_b} \left(N\left(n_b^{gen}, n_c^{gen}, n_q^{gen}\right) \times P_b \times P_c \times P_q \right)$$

Jet-level composition of samples from simulation

Binomial probabilities using well-measured efficiencies

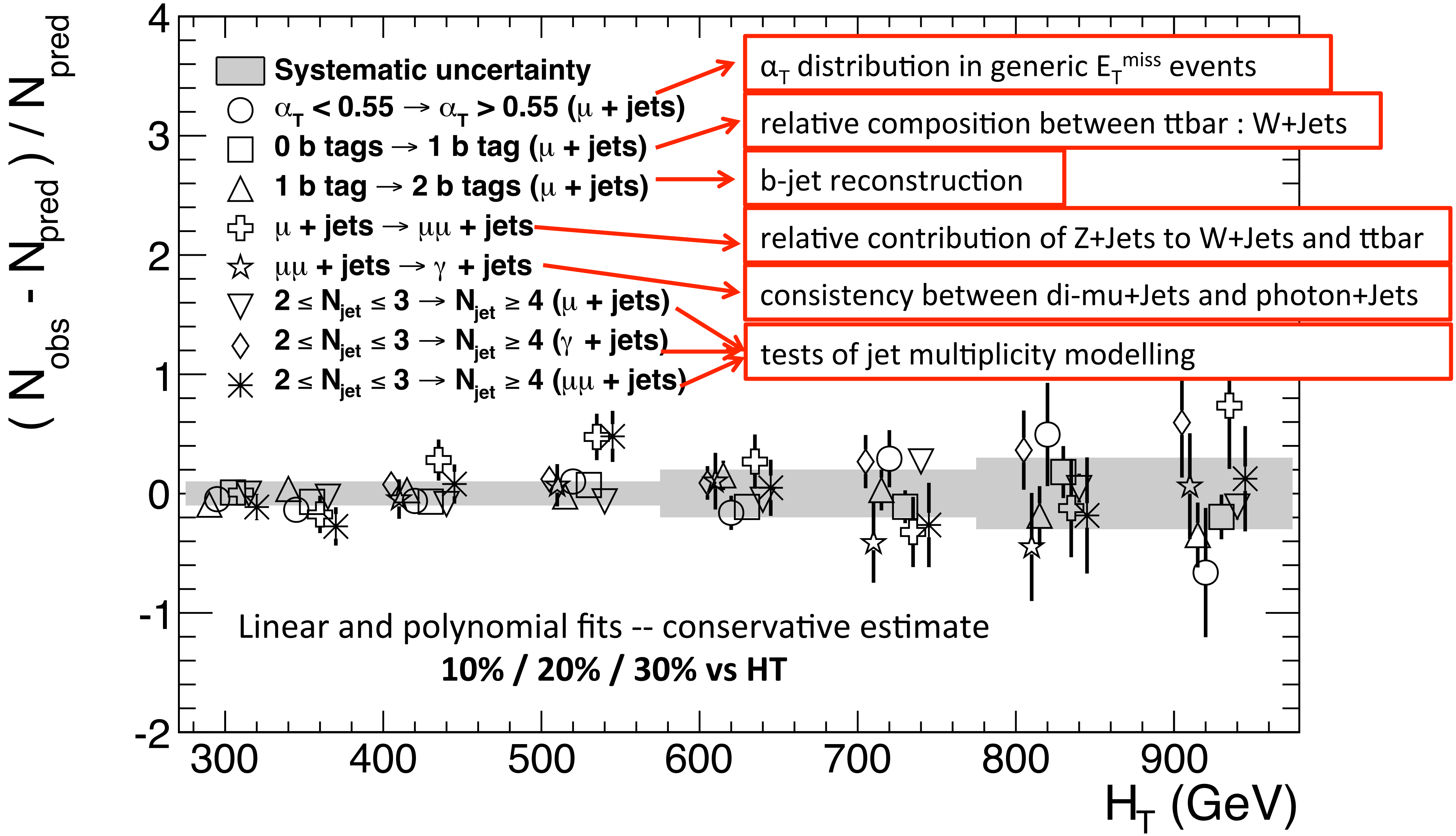


Blue/Red = b-tagged / not-b-tagged
Solid/Dashed = generator / reco jet

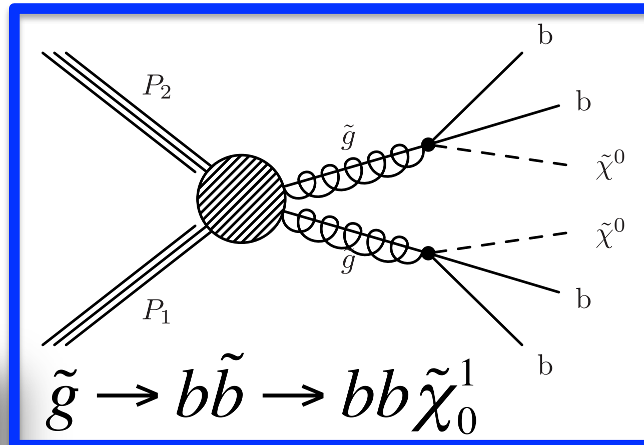
0-leptons: alphaT

CMS-SUS-12-028_8TeV_11/fb
arXiv:1303.2985

Determination of systematic uncertainties with comprehensive suite of closure tests probing all aspects of analysis. N_{jet} >= 4 category:



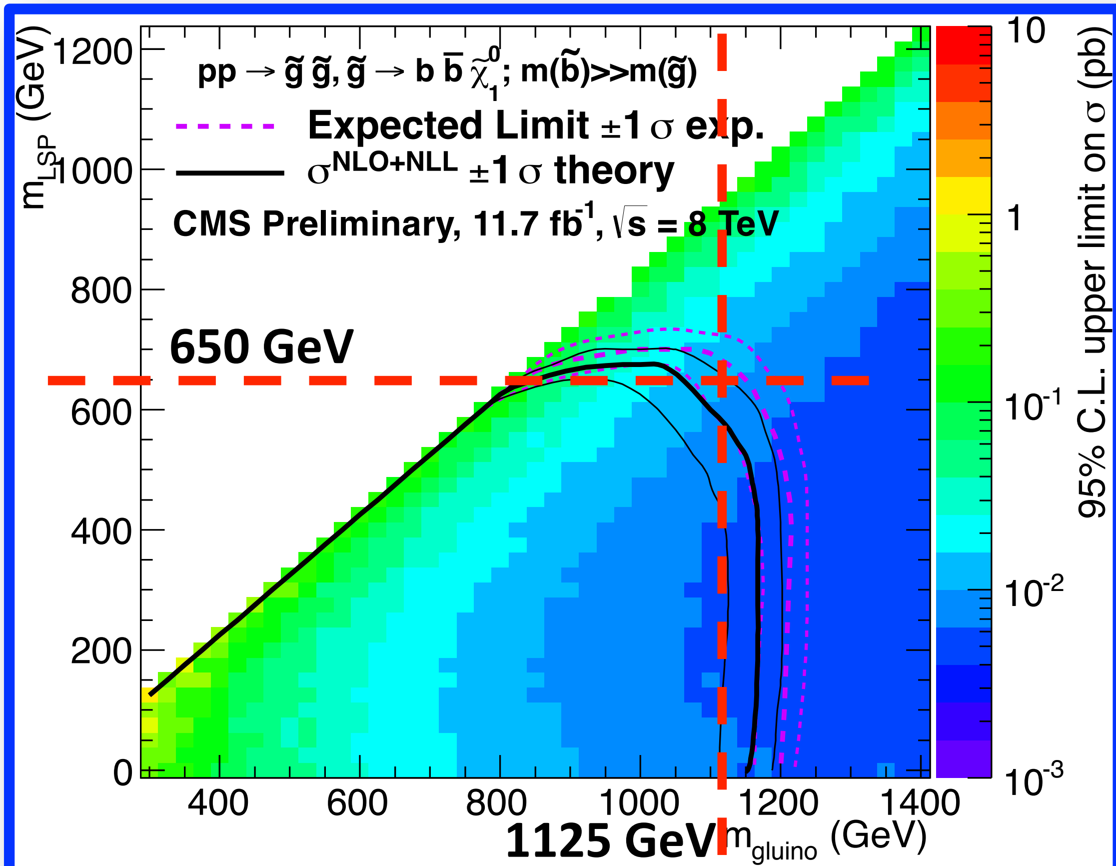
0-leptons: alphaT



Interpretation: gluino induced bottom-squark production

- **The colour scale represents the upper limit on the cross-section (pb) assuming 100% Branching Ratio (BR)**
  - not always shown on these plots!

LSP mass



gluino/SUSY mass

Take-home points for this analysis limit:

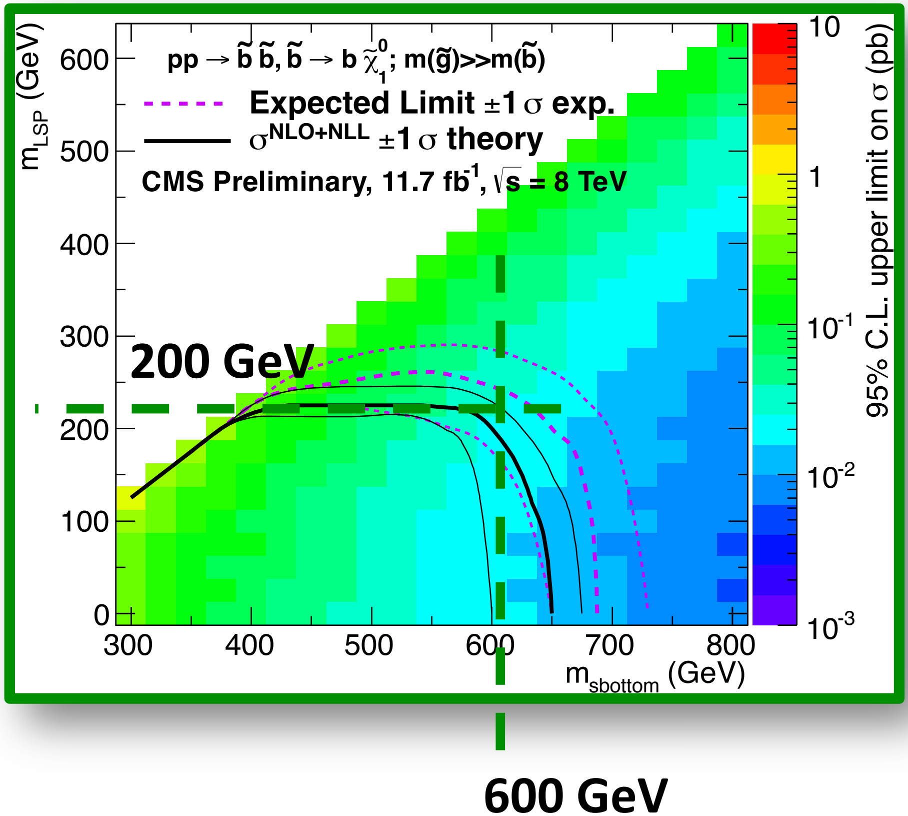
- Best observed limit on gluino mass in this model: 1125 GeV
  - assuming 100% BR
- Limits hold up to an LSP mass of 650 GeV
  - assuming 100% BR

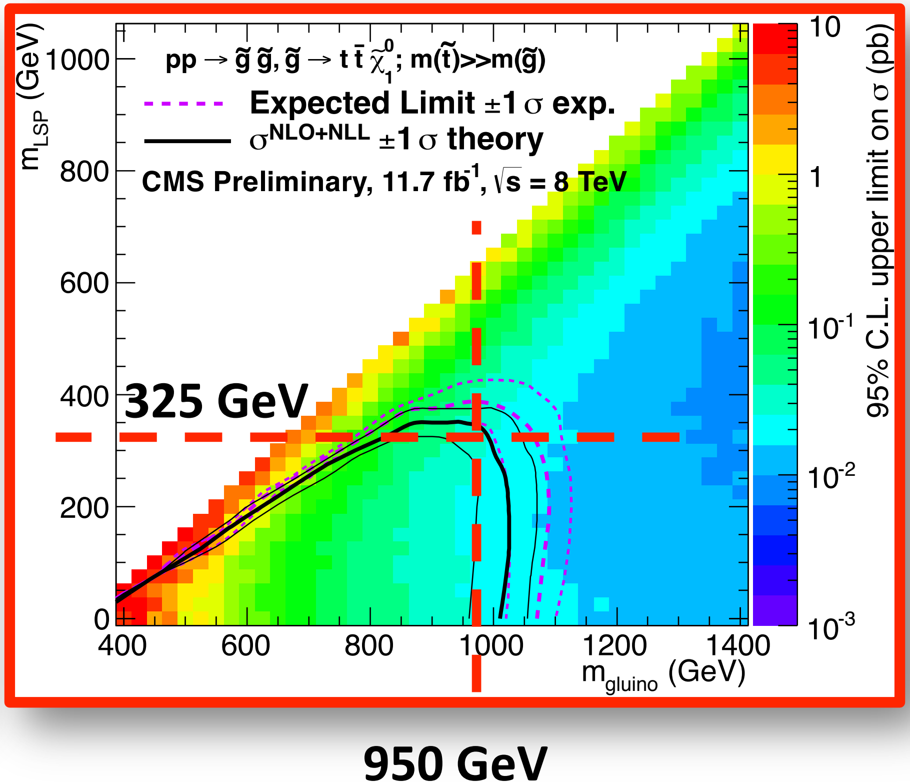
0-leptons: alphaT

CMS-SUS-12-028_8TeV_11/fb
arXiv:1303.2985

Interpretations in:

- gluino induced top-squark production
- direct bottom-squark production





Other 0-lepton final states

0-leptons: Effective mass

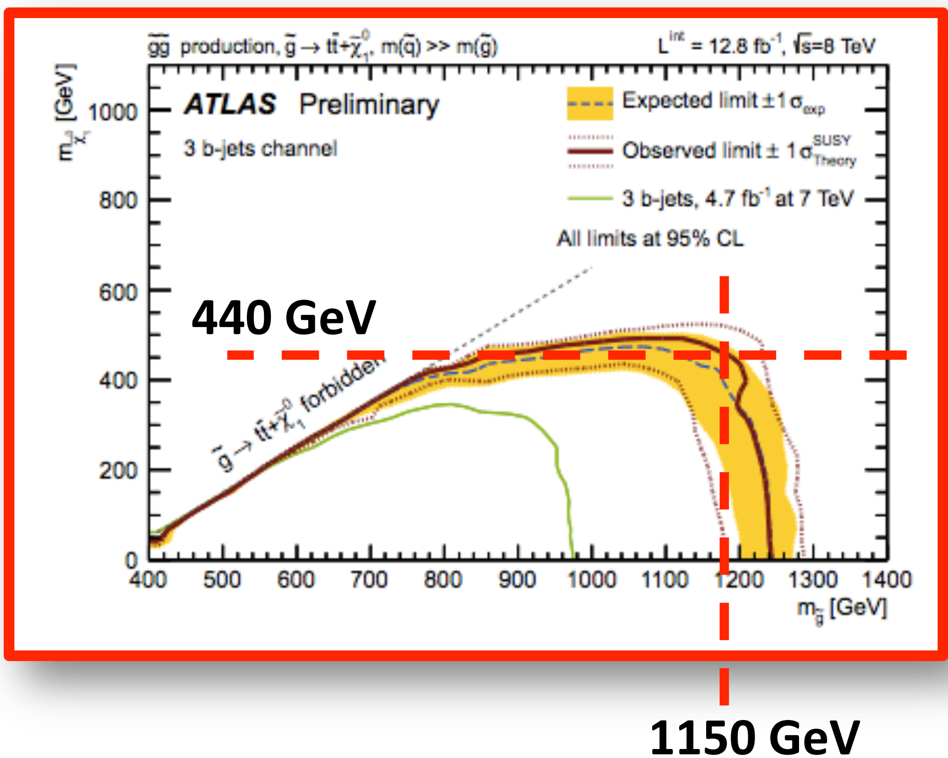
Dedicated search with at least 3 b-jets
- specifically targeting gluino induced 3G production

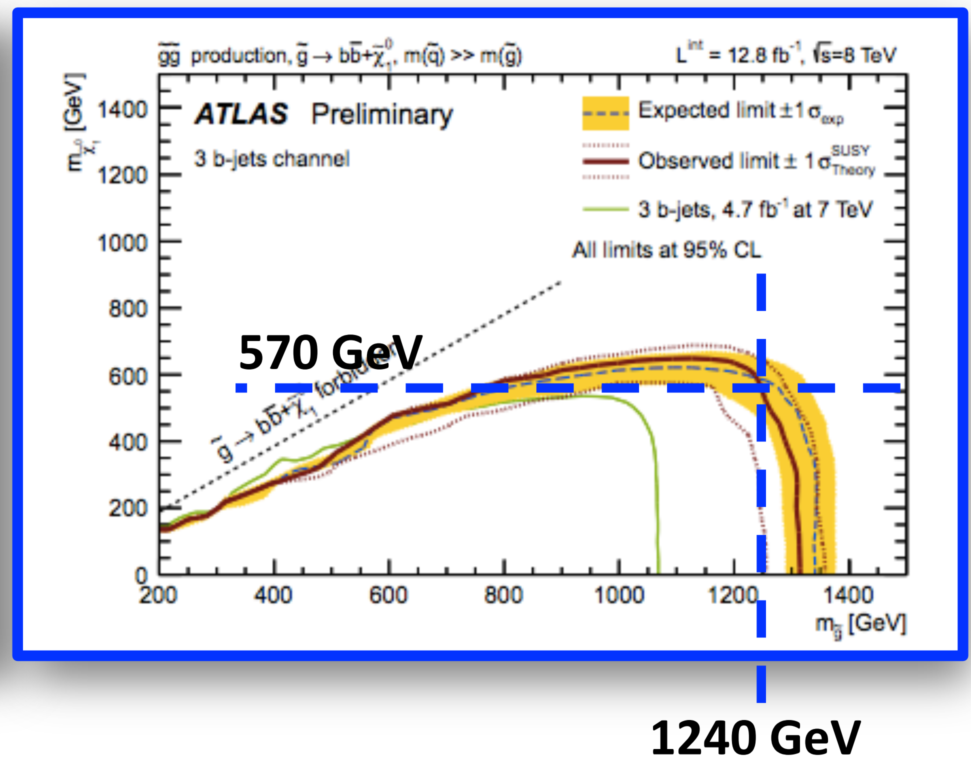
Discriminators:
- Effective mass (at least 900 GeV, 3 bins)
- Number of jets (>=4, >=6)
- DeltaPhi(jets, E_T^{miss}) > 0.4
- E_T^{miss} >= 200 GeV

Data driven background estimates:
- ttbar+jets, multi-jet

Interpretations shown
- **gluino induced top-squark production**
- **gluino induced bottom-squark production**

(see backup slides for ATLAS 0-lepton searches targeting direct 3G production)





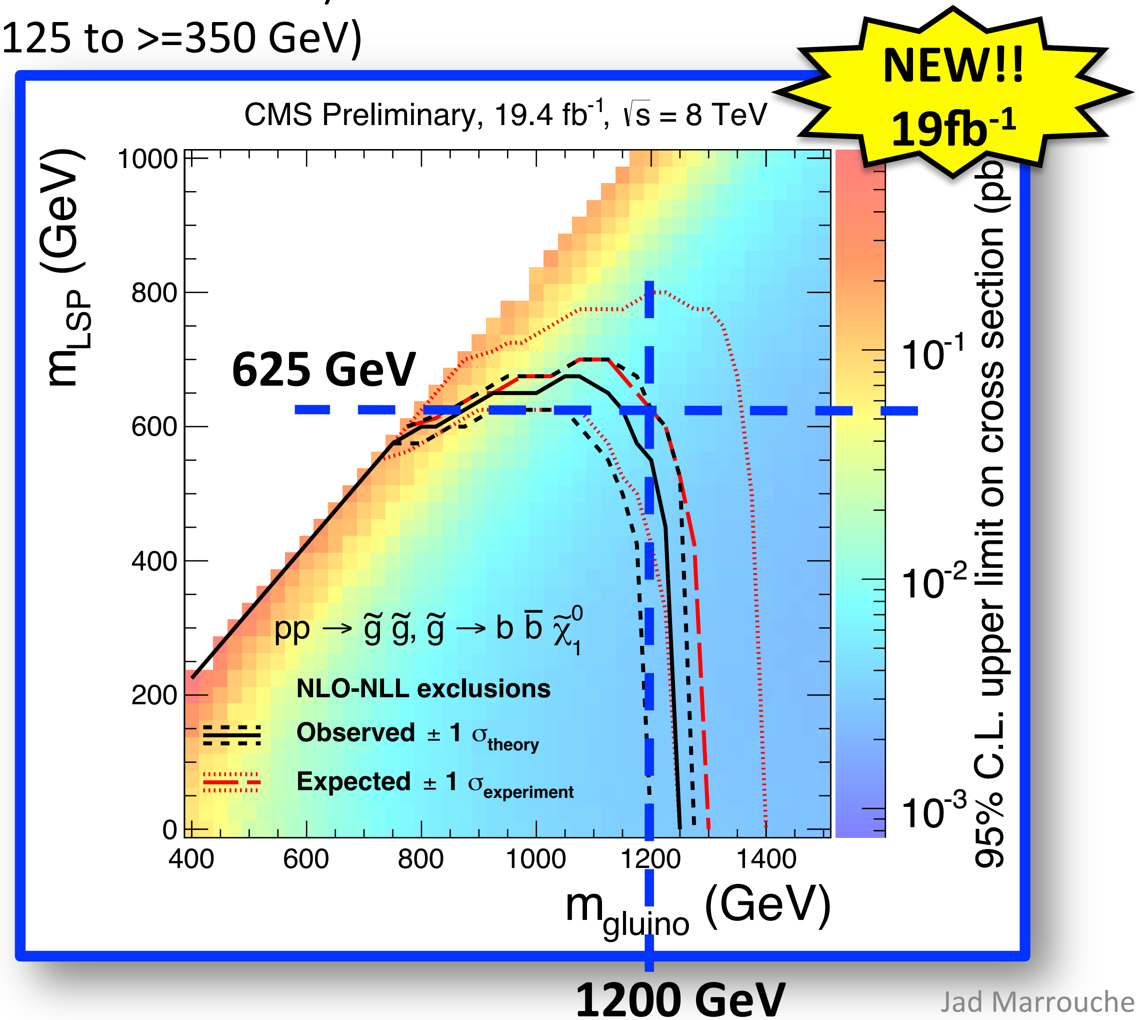
0-leptons: H_T vs E_T^{miss} vs b-tag fit

Inclusive search with at least 3 jets
- targeting gluino induced 3G production

Binned in (48 Signal Regions)
- Number of b-jets (1,2,>=3)
- H_T (4 bins from 400 to >=1000 GeV)
- E_T^{miss} (4 bins from 125 to >=350 GeV)

Background estimates from control regions in data, simultaneously fit

Interpretation shown
- **gluino induced bottom-squark production**



1-lepton final states

1-lepton: Dedicated stop search

ATLAS-CONF-2012-166_8TeV_13/fb

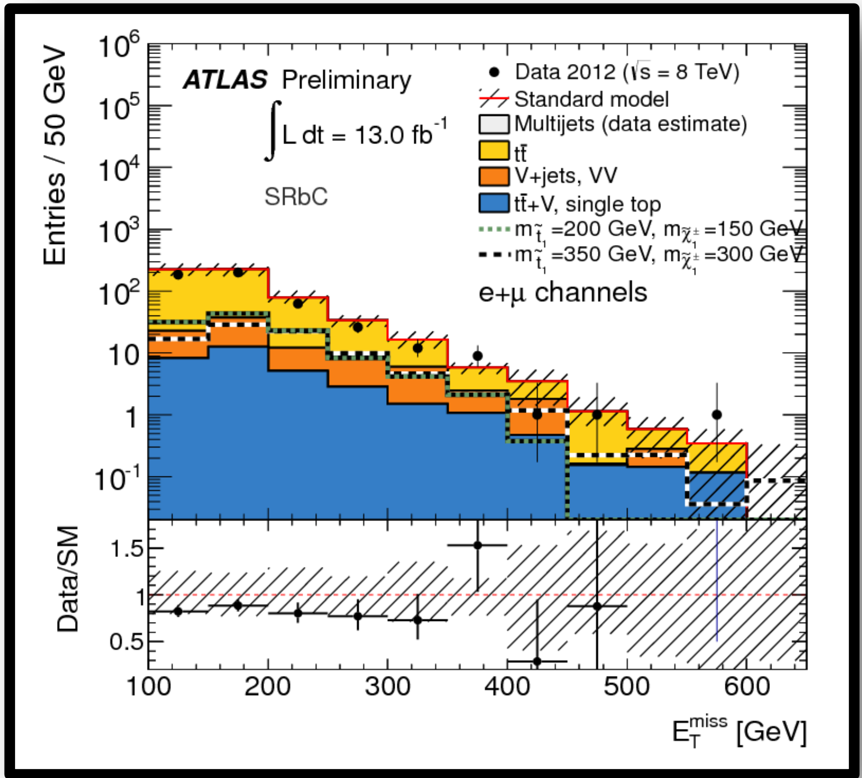
Targeting direct top squark production:
- an isolated electron or muon
- at least 4 jets
- at least 1 b-jet
- E_T^{miss} at least 150 GeV

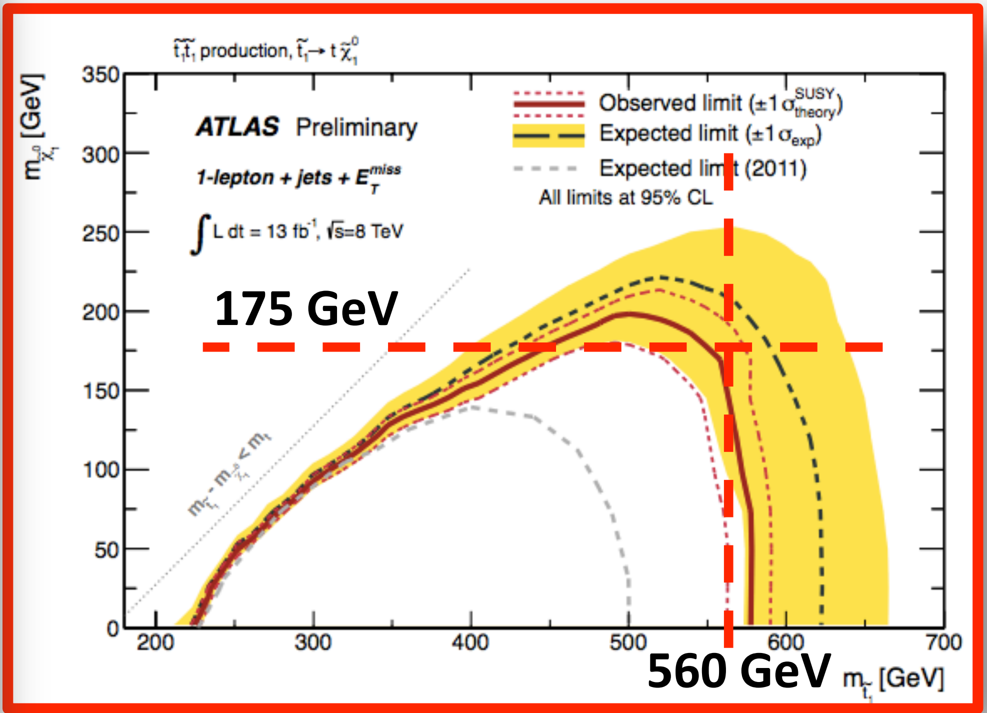
6 signal regions defined by various binning in
- transverse mass and variants of MT2

Main backgrounds: di-leptonic ttbar, W+jets

Interpretation shown
- **direct top-squark pair production, decay via neutralino**

CMS search details in backup





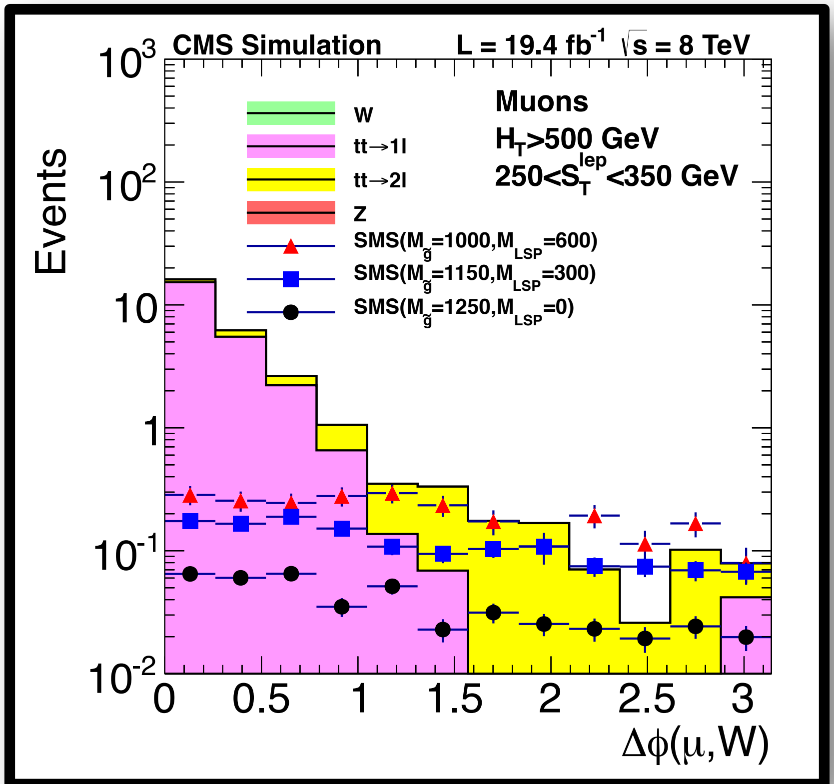
1-lepton: Gluino-induced stop search

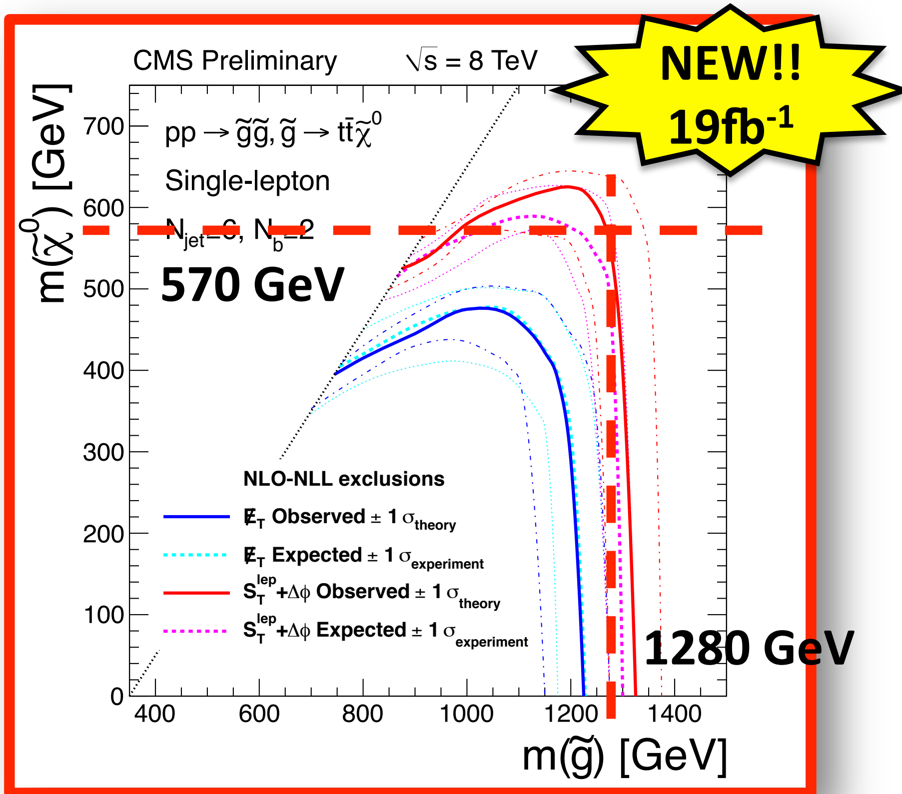
Targeting gluino induced top squark production
- at least 6 jets
- at least 2 b-jets
- an isolated electron or muon

Two independent analyses using different data-driven methods to estimate backgrounds
- Primarily ttbar+jets

1. Lepton Spectrum : use lepton pT spectrum to estimate neutrino pT spectrum.
- *Use HT(>500) and ETmiss(>250)*

2. DeltaPhi(vec(ETmiss+lepton), lepton)
use correlation between azimuthal angle of W-direction and lepton as discriminator
- *Bin in S_T = [lepton pT + E_T^{miss}] (>250)*





2-lepton final states

2-leptons (Opposite Sign)

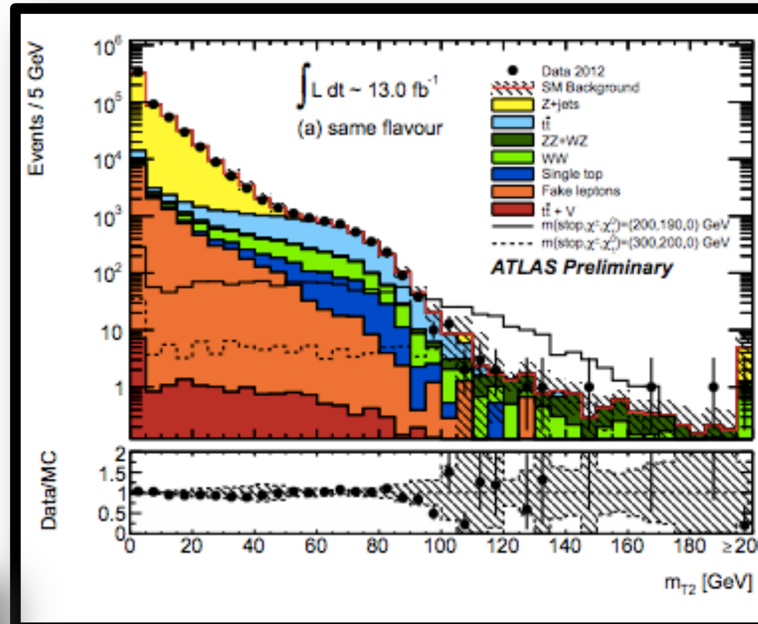
ATLAS-CONF-2012-167_8TeV_13/fb

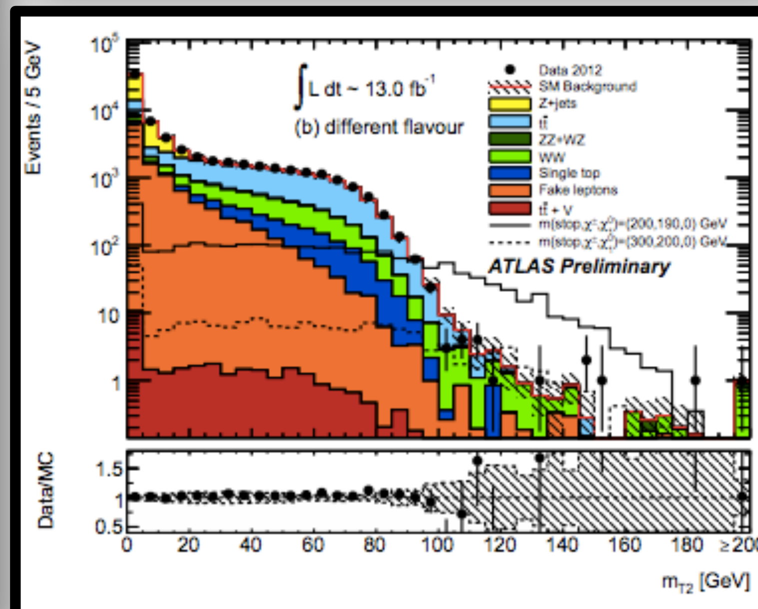
Search requiring
- 2 isolated opposite-sign electrons or muons

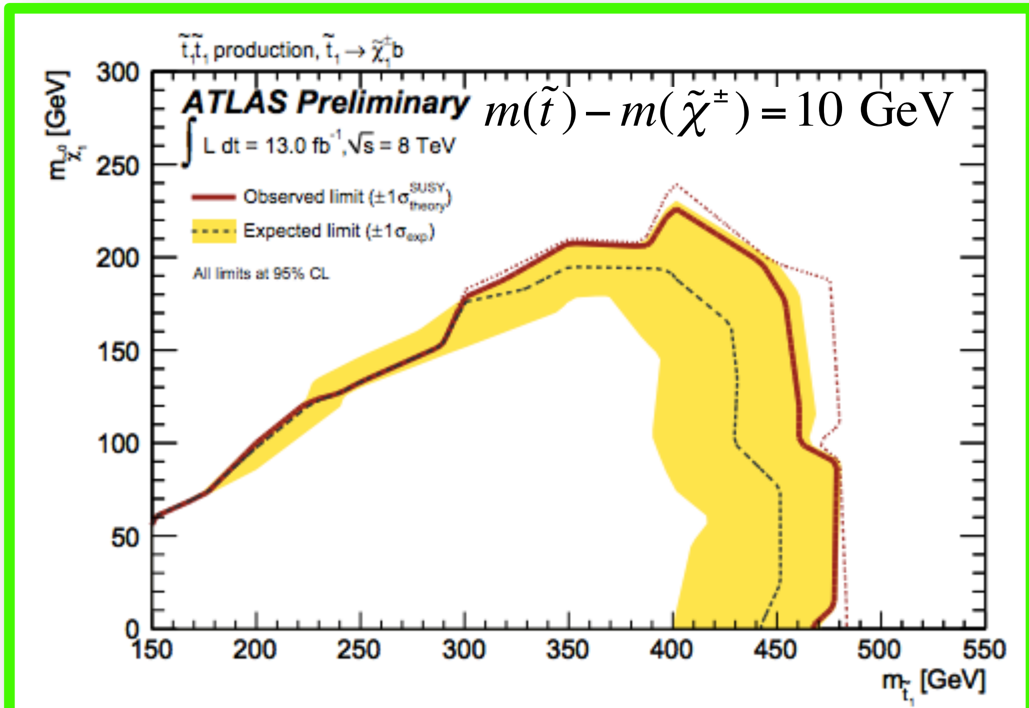
Discriminators
- **M_T2** (like transverse mass but 2 "neutrinos")
- Boost vector = vec(ETmiss+ pT(lep1)+ pT(lep2))

Main Backgrounds:
- top production, diboson (data-driven)

Interpretations in
- **direct top-squark production, decay via chargino**







2-leptons (Same Sign)

CMS-SUS-12-017_8TeV_11/fb

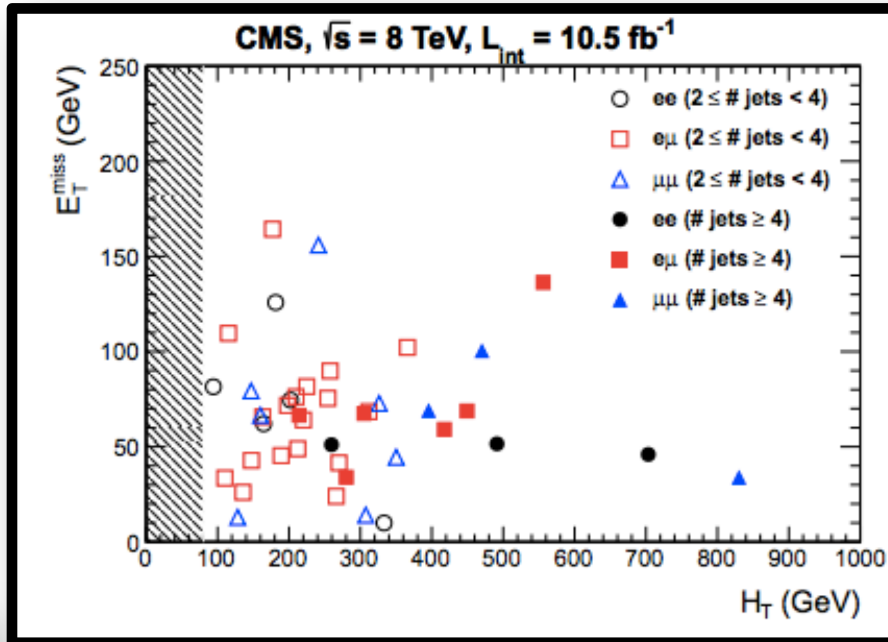
arXiv:1212.6194 -- accepted by JHEP

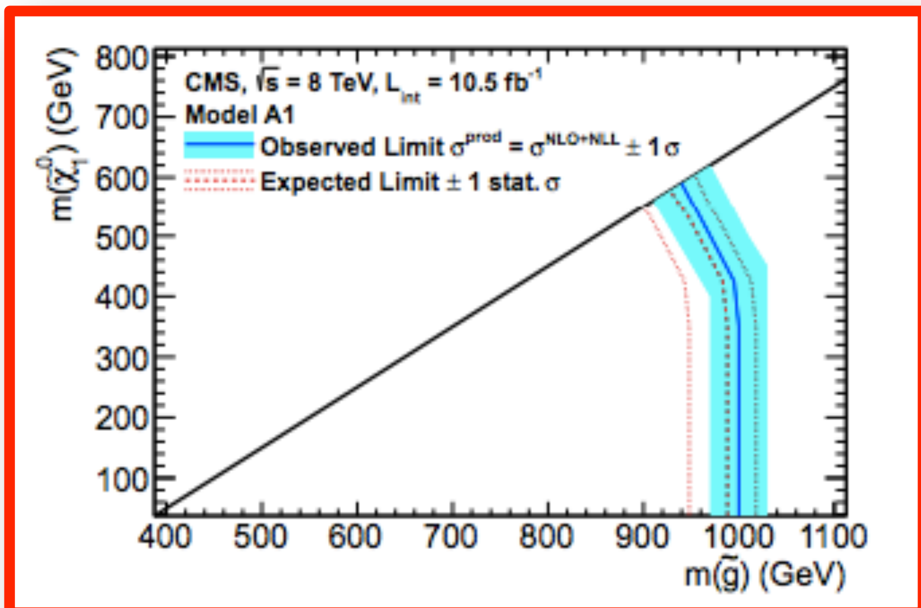
Inclusive search requiring
- 2 isolated same-sign electrons or muons
- at least 2 b-jets

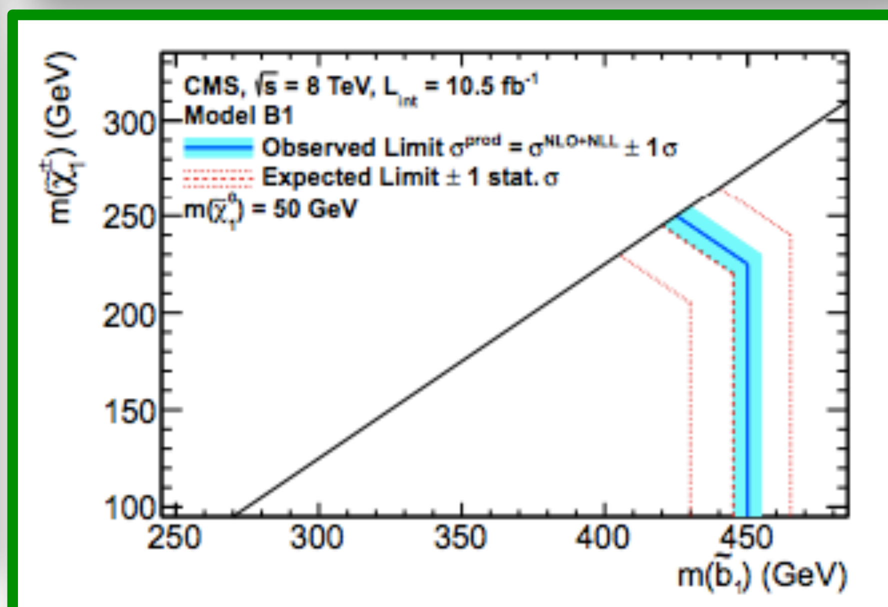
8 Signal Regions with
- **HT range from >80 to >320**
- **E_T^{miss} range from >0 to >120**

Backgrounds:
- rare SM decays, fake leptons, charge flips

Interpretations in
- **gluino induced top-squark production**
- **direct bottom-squark, decay via chargino**







2-leptons (Same Sign)

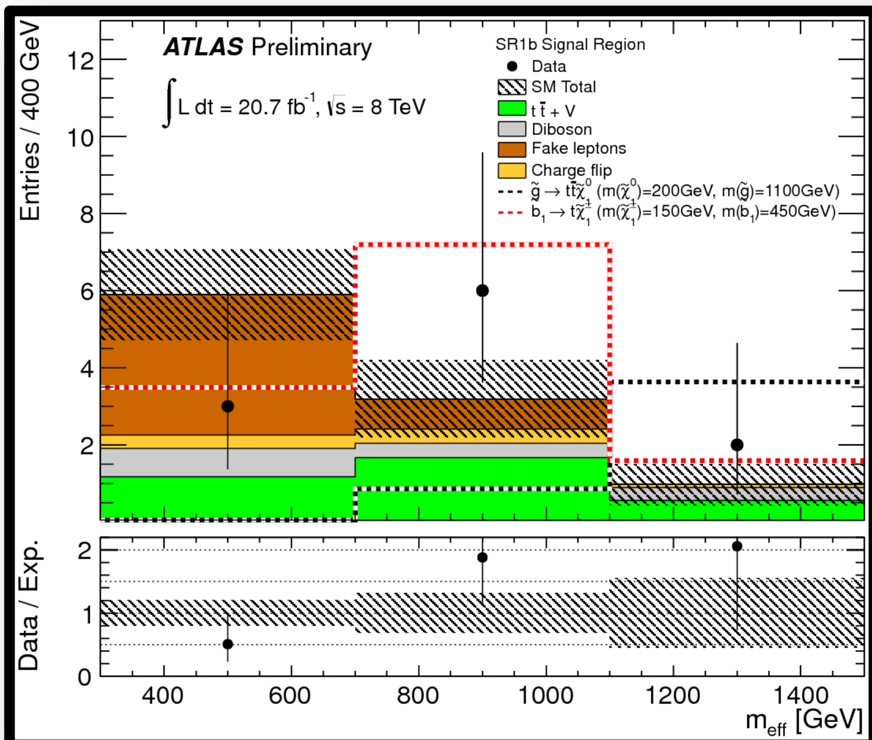
ATLAS-CONF-2013-007_8TeV_20/fb

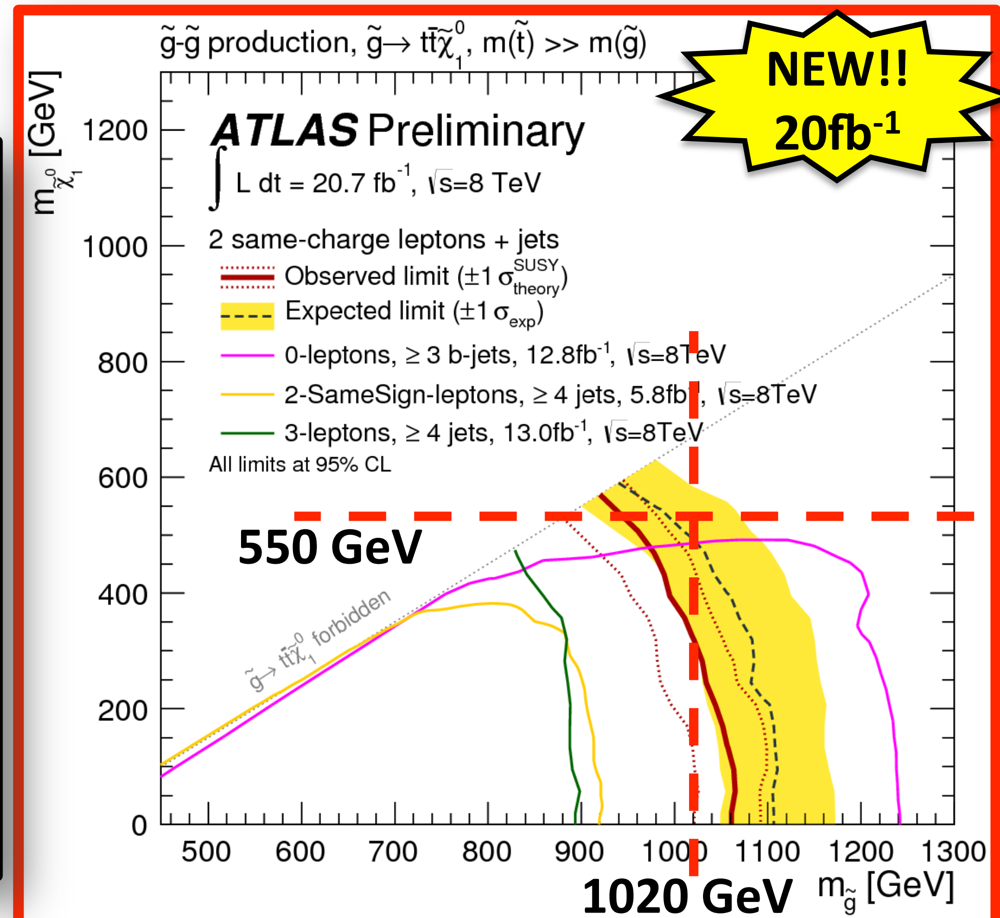
Dedicated search requiring
- 2 isolated same-sign electrons/muons

Three Signal Regions:
- **Effective mass**, transverse mass, E_T^{miss}
- Number of b-jets (0, >=1, >=3)
- Number of jets (>=3, >=5)

Backgrounds:
- rare SM decays, fake leptons, charge flips

Interpretations shown
- **gluino induced top-squark production**



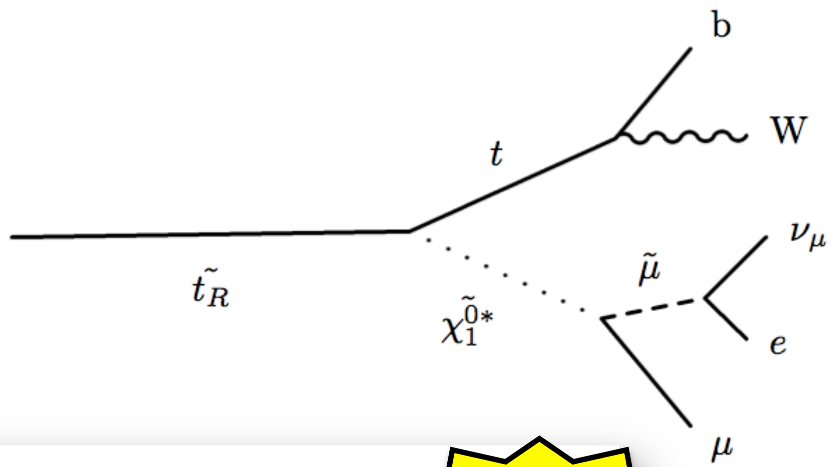


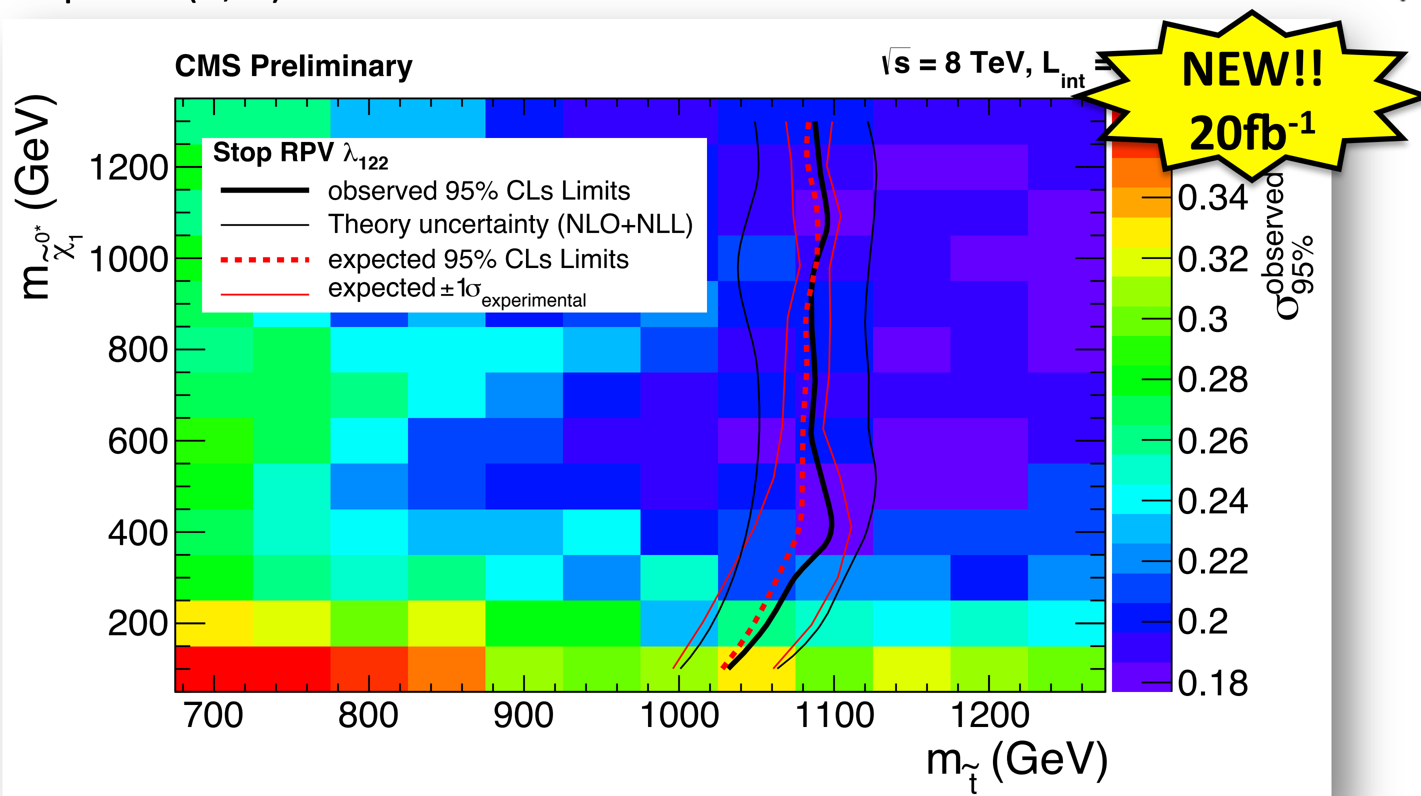
Multi-lepton final states

R-Parity Violating Stop Search

Based on events with not as much E_T^{miss}
- 3 or 4 reconstructed leptons
- at least 1 b-tag

Bin exclusively in:
- S_T = scalar sum of E_T^{miss}, jet-pT and lepton-pT
- Number of hadronic taus (0, 1)
- Number of leptons (3, 4)



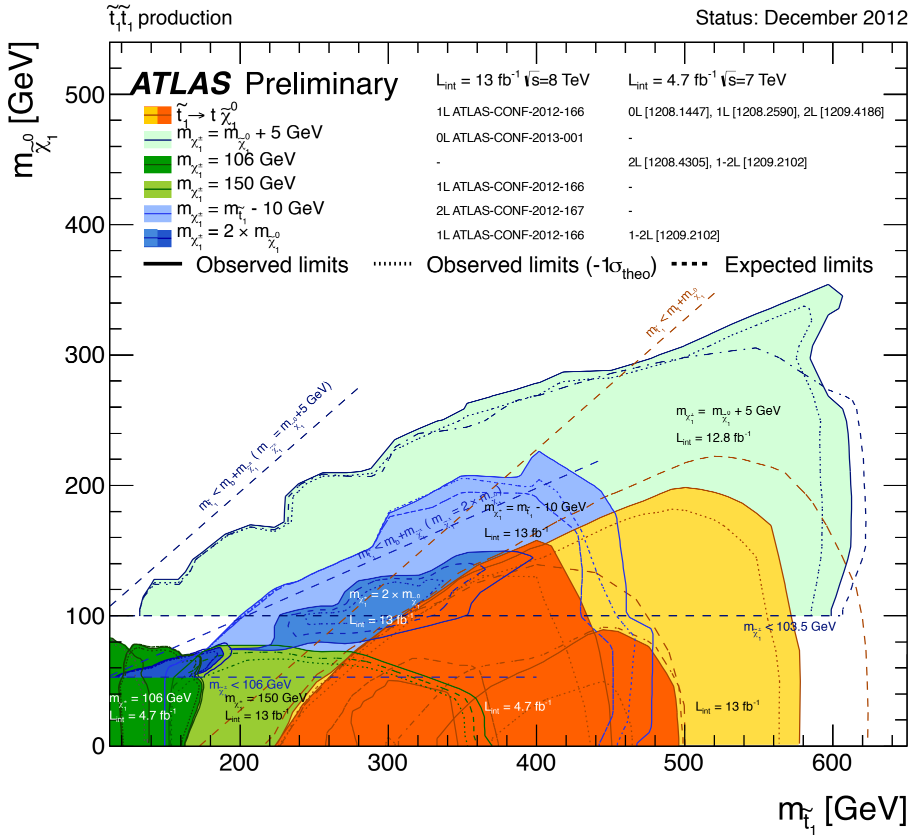


 LHE files provided by Jared Evans and Yevgeny Kats (arxiv:1209.0764)

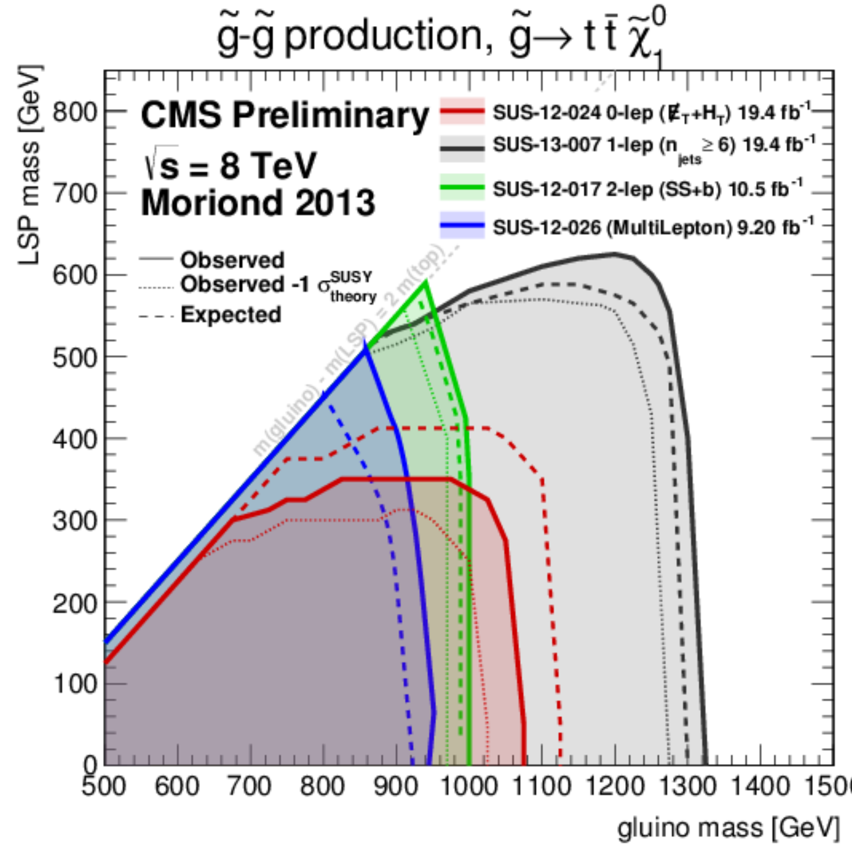
Summary Plots

100% BR

ATLAS direct stop production



CMS gluino-induced stop production

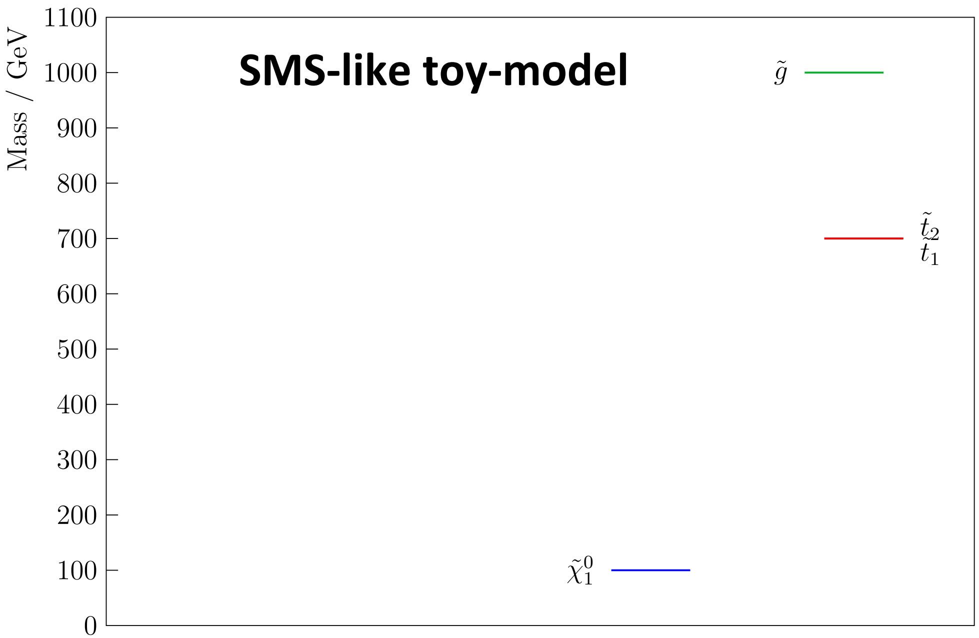


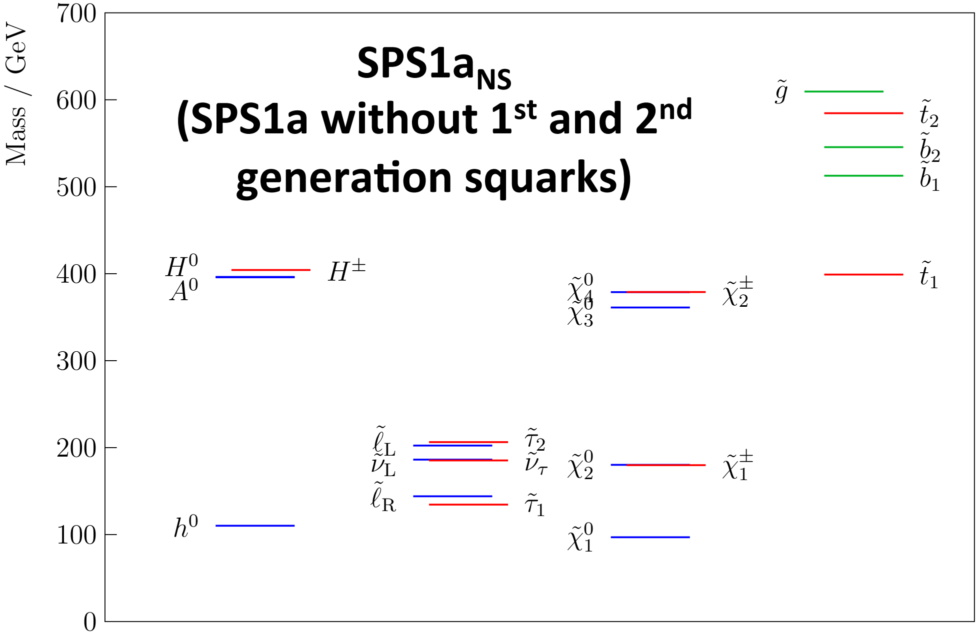
R-Parity Conserving	Direct stop (neutralino)	Direct sbottom (neutralino)	Gluino-induced stop	Gluino induced sbottom
Best limit:	560 GeV	600 GeV	1280 GeV	1240 GeV
No limit beyond LSP:	175 GeV	300 GeV	570 GeV	650 GeV

But what if BR < 100%?

The following slides are based on the work of JM and Oliver Buchmueller, to be submitted shortly.

But what if BR < 100%?





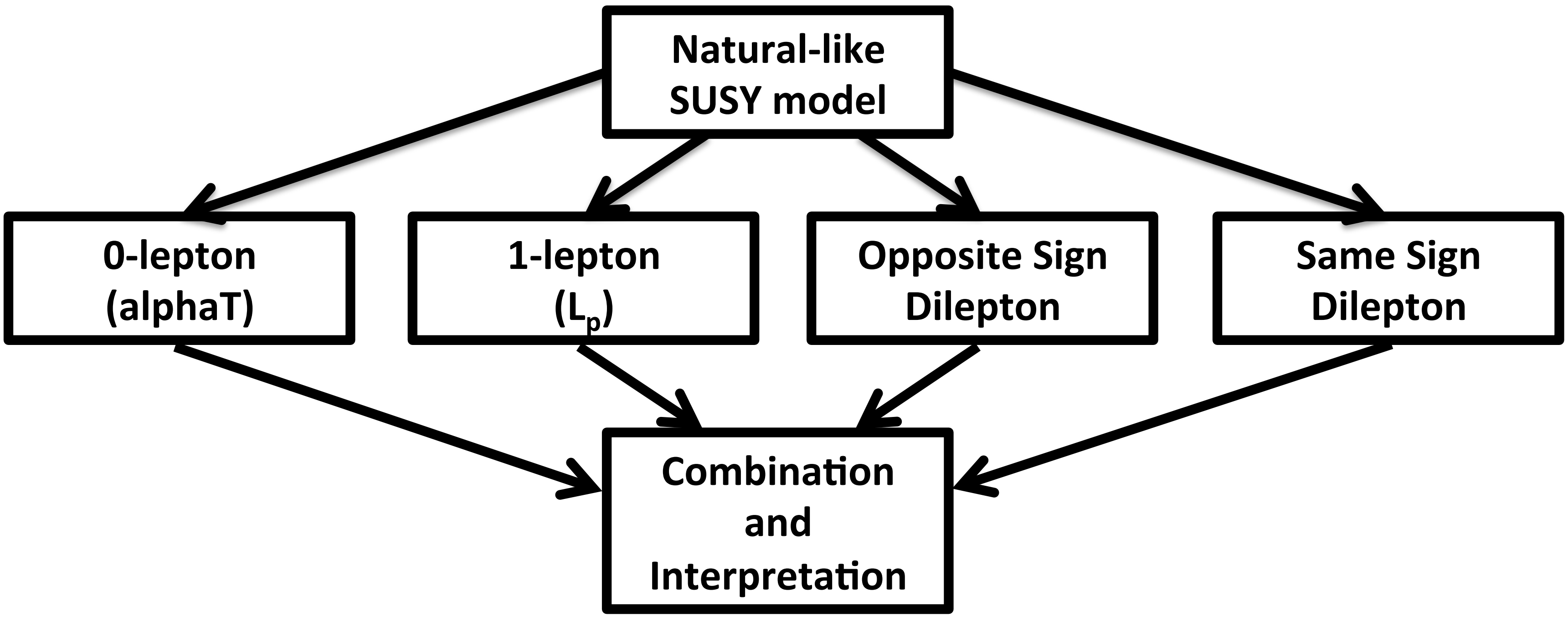
i.e. are the mass limits quoted valid when going from a simplified model to a realistic and complete SUSY spectrum?

Naively, expect that only a combination of relevant searches has any chance of recovering these limits

But what if BR < 100%?

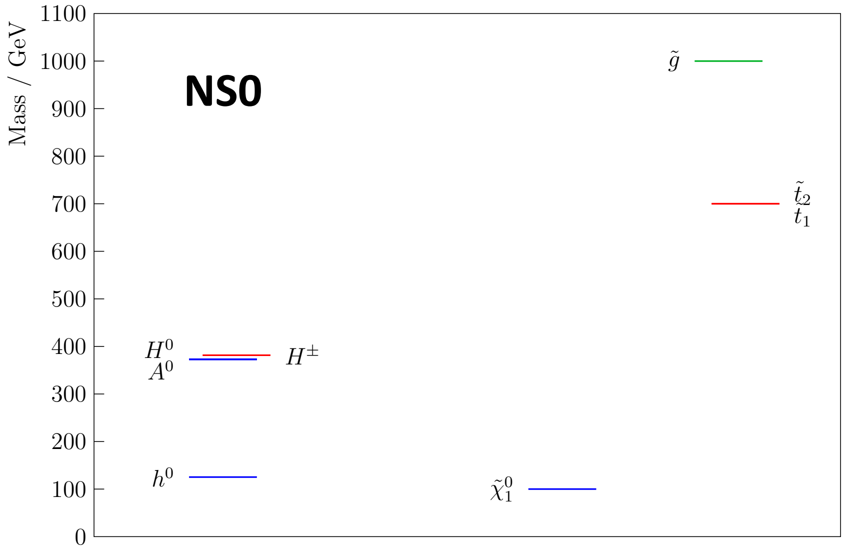
General idea

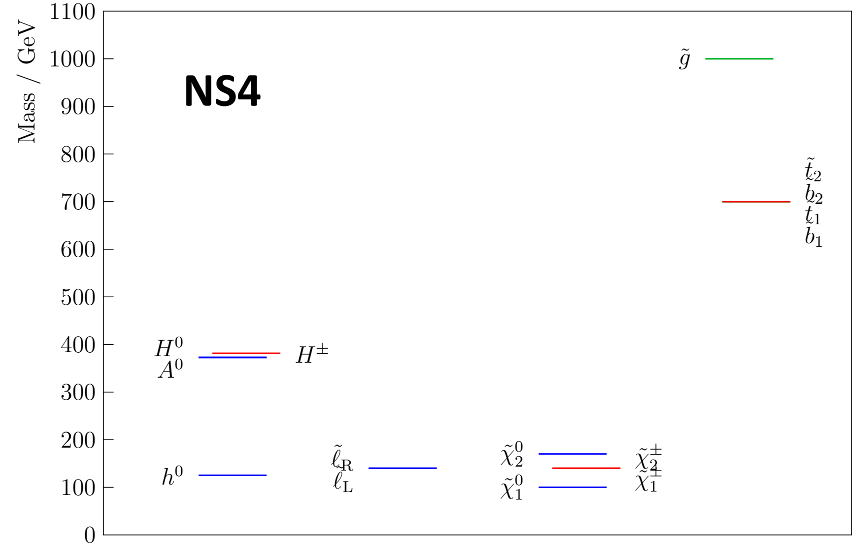
- Define a more realistic class of "Natural" SUSY model to consider
- Analyse a consistent set of inclusive topology searches.
- Since 2011 analyses are complete, use set of four CMS searches, published using 7 TeV dataset
- Combine the likelihoods together
- Test dependence of mass limits on complexity



Our Natural-like SUSY spectra

First we define concept of Natural-like SUSY spectra in terms of increasing complexity, which we will use to benchmark our concept of universal limits

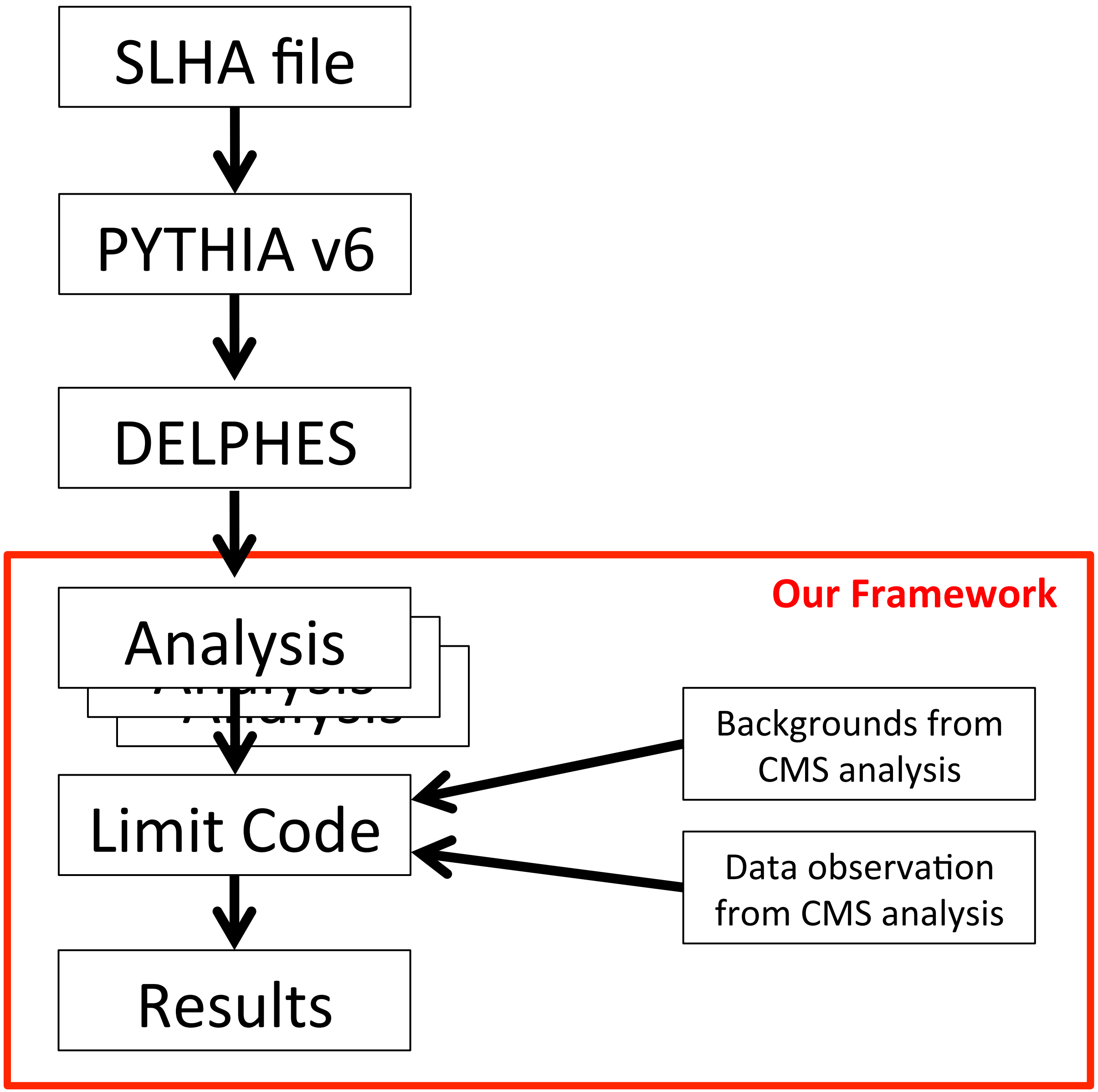




Increasing complexity →

Spectra	NS0	NS1	NS2	NS3	NS4
sparticle content	$\tilde{g}$ $\tilde{t}_1, \tilde{t}_2$ $\tilde{\chi}_0^1$	$\tilde{g}$ $\tilde{t}_1, \tilde{t}_2, \tilde{b}_1$ $\tilde{\chi}_0^1$	$\tilde{g}$ $\tilde{t}_1, \tilde{t}_2, \tilde{b}_1$ $\tilde{\chi}_0^2$ $\tilde{\chi}^\pm$ $\tilde{\chi}_0^1$	$\tilde{g}$ $\tilde{t}_1, \tilde{t}_2, \tilde{b}_1, \tilde{b}_2$ $\tilde{\chi}_0^2$ $\tilde{\chi}^\pm$ $\tilde{\chi}_0^1$	$\tilde{g}$ $\tilde{t}_1, \tilde{t}_2, \tilde{b}_1, \tilde{b}_2$ $\tilde{\chi}_0^2$ $\tilde{\chi}^\pm, \tilde{\ell}_{L,R}$ $\tilde{\chi}_0^1$

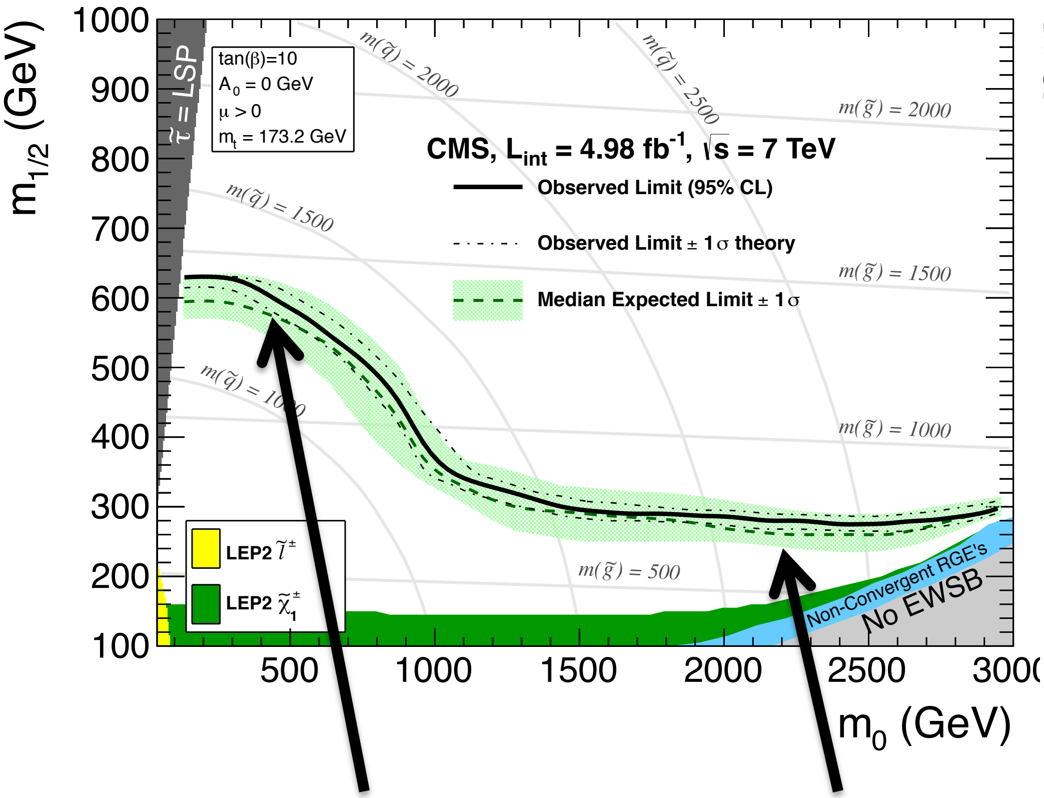
Our Analysis Framework

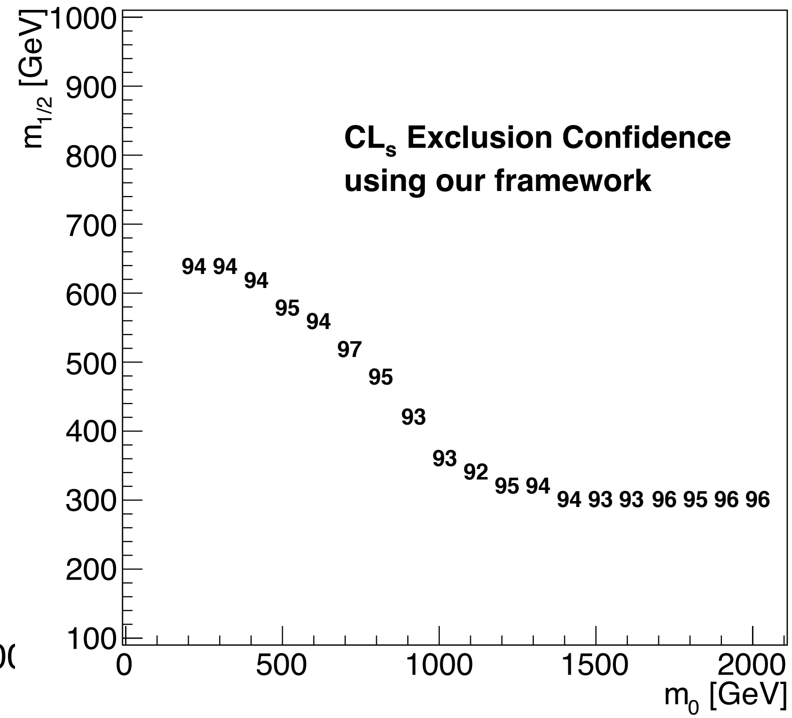


Validation of searches

As a stringent test of (a) the implementation of searches, (b) statistical treatment of results and (c) effectiveness of DELPHES simulation for our needs, try to reproduce limits in a complete physics model like the CMSSM

- Example using alphaT search:



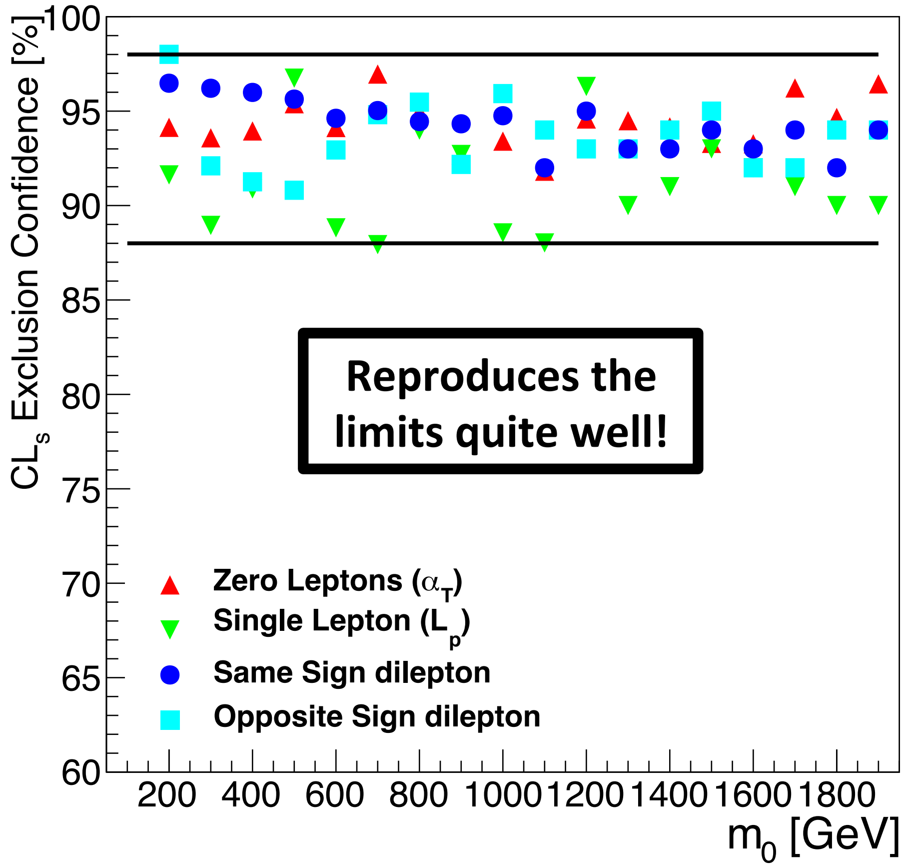


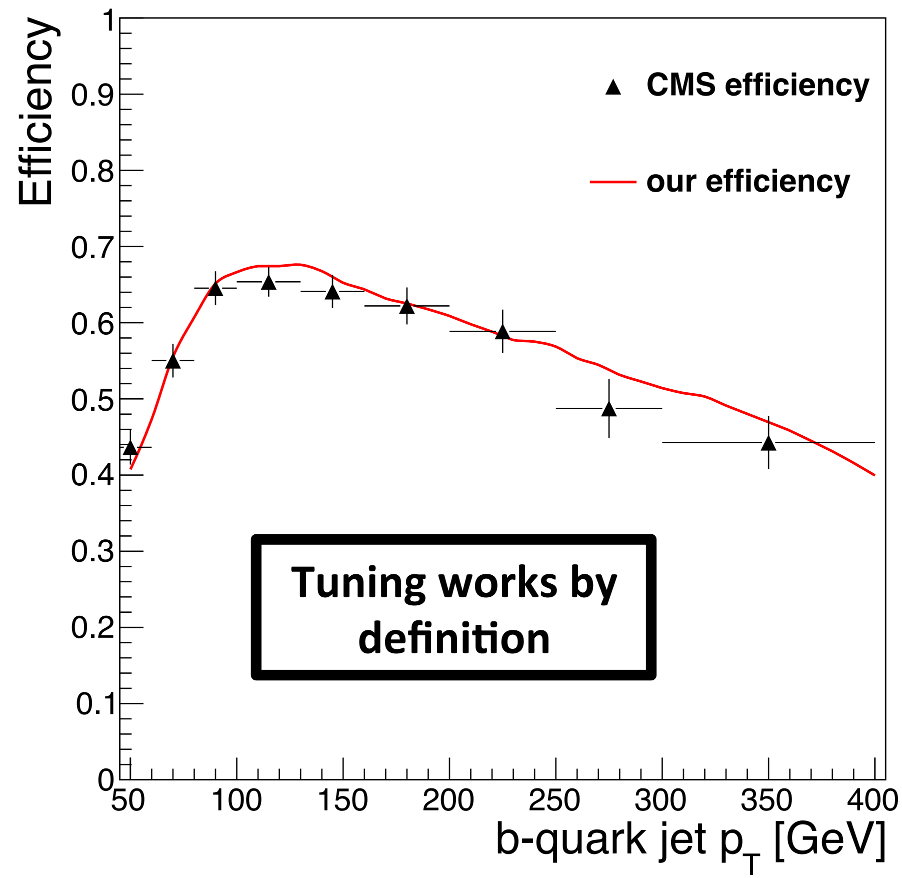
Mainly squark-squark **Mainly gluino-gluino**

Reproduces the limits quite well!

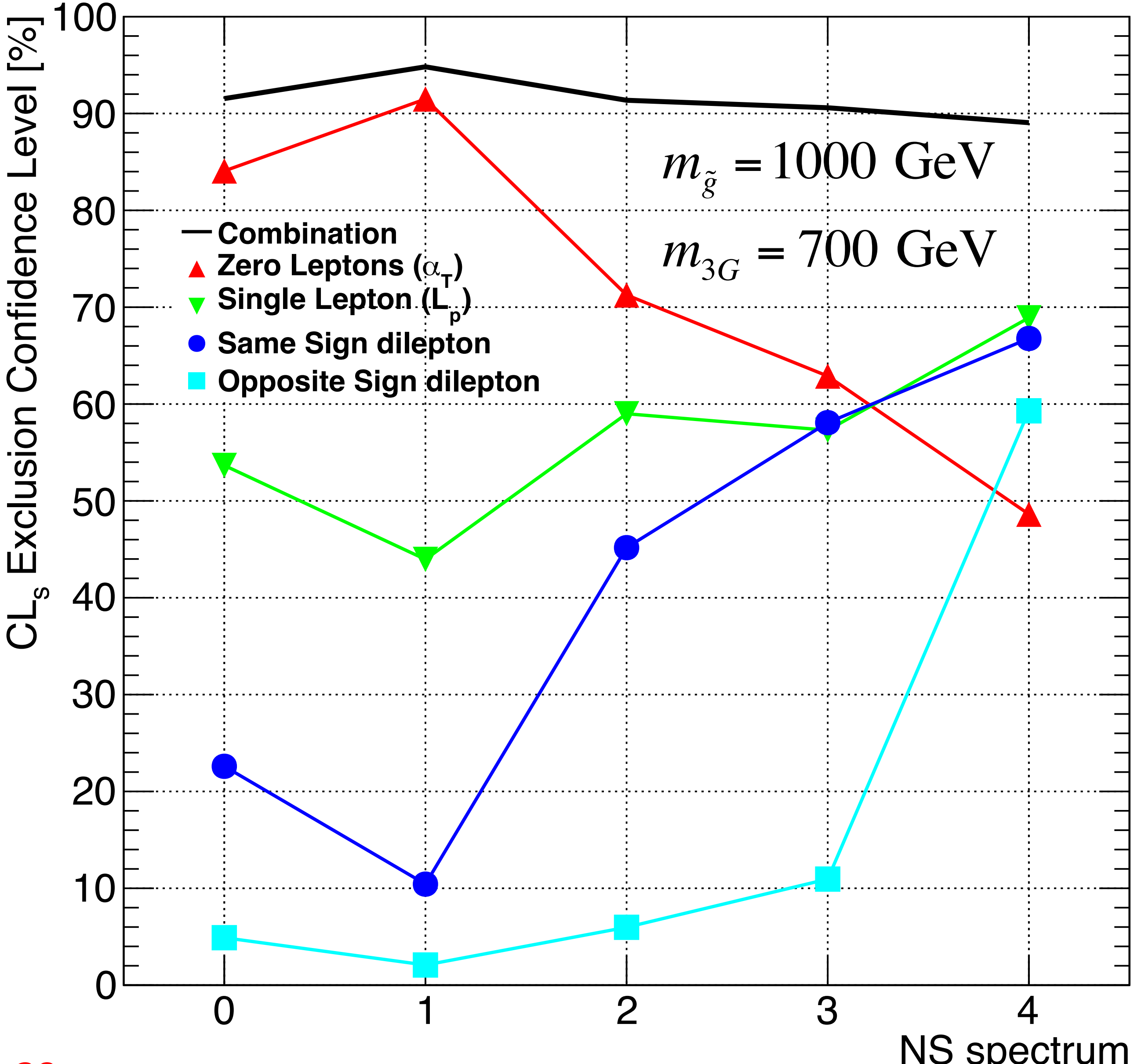
Validation of searches

Adding the other searches and tuning the b-tagging efficiency as reported by CMS in the Same-Sign dilepton paper





Results vs Complexity



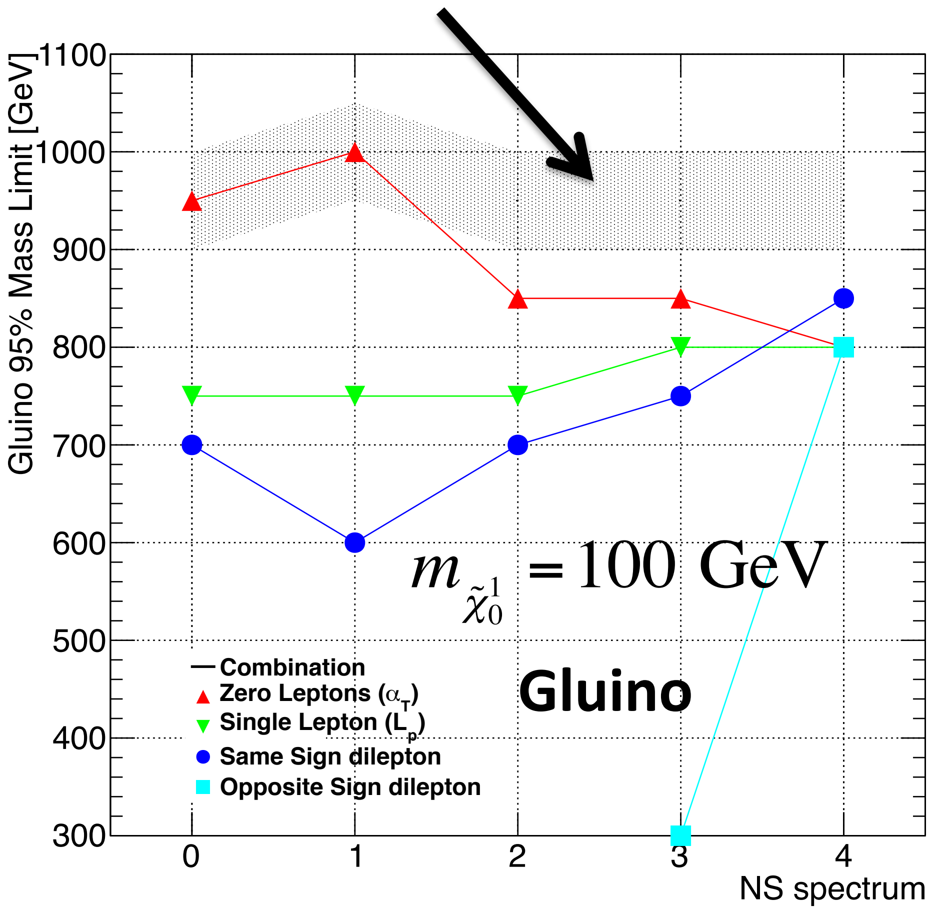
Combination of searches stable

Individual searches exhibit large variations

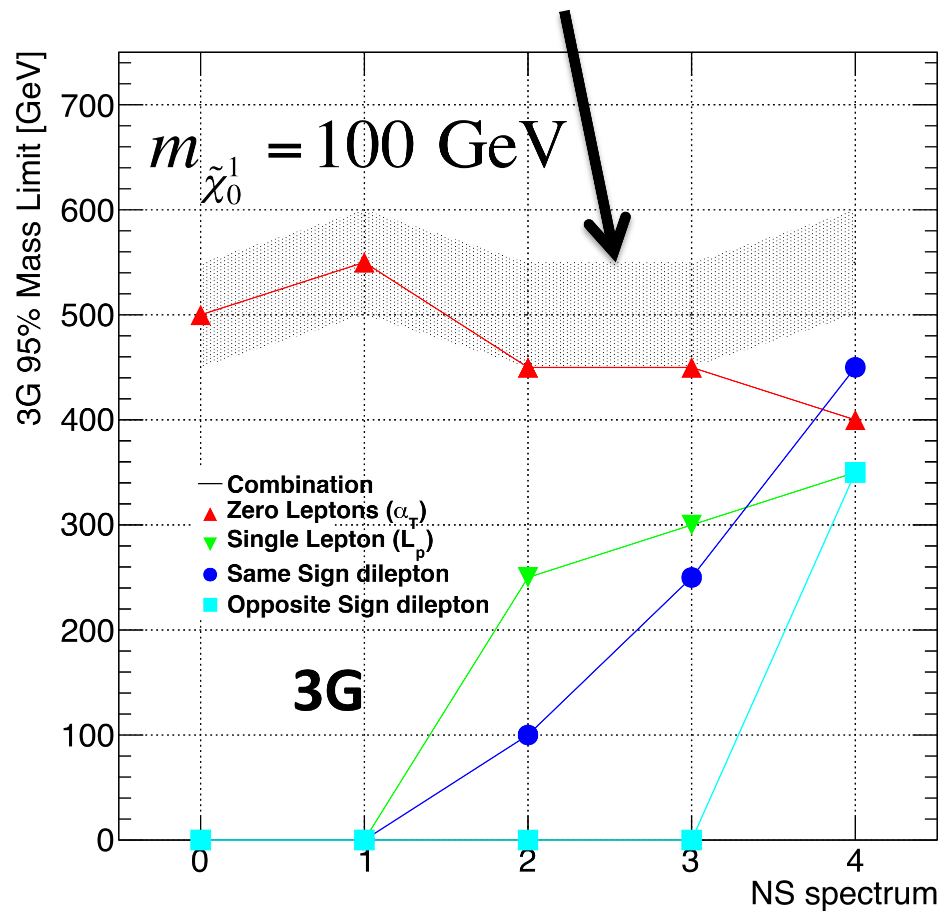
Results vs Complexity

Rather than take one spectra, scan in the gluino vs third-generation squark mass plane for fixed LSP mass = 100 GeV

Limit where gluino mass is ruled out to 95% CL irrespective of 3G mass



Limit where 3G mass is ruled out to 95% CL irrespective of gluino mass



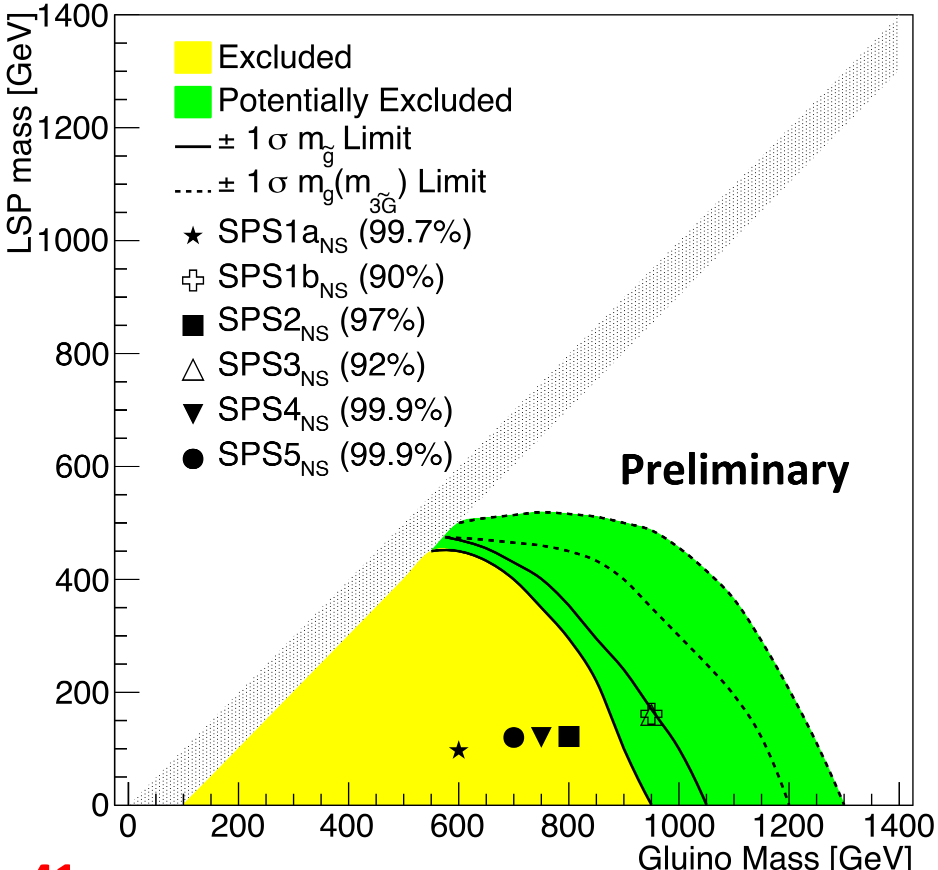
Overall Result: 2011

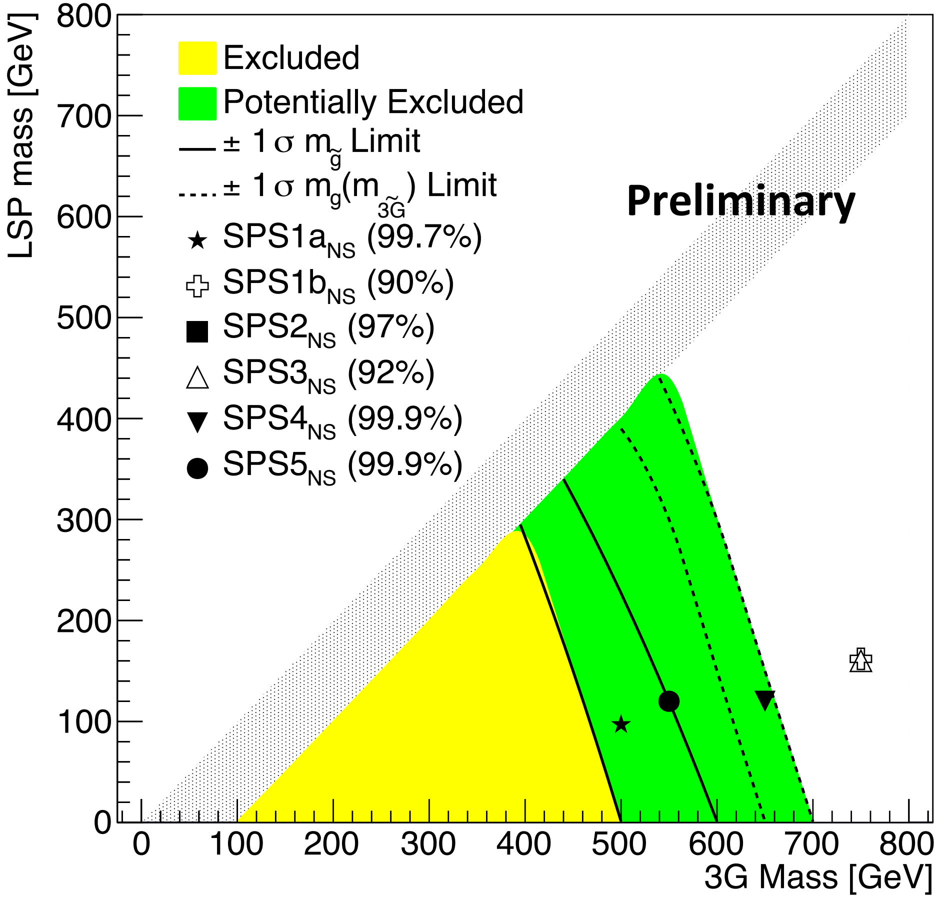
If the gluino mass OR 3G mass lies in the yellow band, the point is excluded

If the gluino mass AND 3G mass lie in the green band, the point may or may not be excluded

If the gluino mass and 3G mass lie in the white and green areas, the point is not excluded

Universal mass limits! Not restricted to "Natural"-like SUSY!





Note:
work to be submitted shortly

Concept of universal mass limits extremely powerful.

Currently adding 3rd dimension of first and second generation squarks.

Work also includes analysis of available 2012 data and prediction for full dataset.

Summary: Experimental Searches

- Focus of experimental searches shifting toward "natural" solution of hierarchy problem; requires light top and bottom squarks and gluinos
  - Should be within reach of LHC
- Comprehensive array of searches at ATLAS and CMS targeting these particles
  - Many discriminators, search regions, final states
  - Nothing found so far ☹
- Placed stringent constraints in mass range relevant for hierarchy problem in the context of simplified models
  - Gluino mass: 1.2-1.3 TeV, 3G mass: 500-600 GeV (100% assumptions)
- Expect significant improvement in sensitivity at 14 TeV
  - Much of the remaining SUSY parameter space yet to be probed
  - Stay tuned for future results
- More information:
  - https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS
  - https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

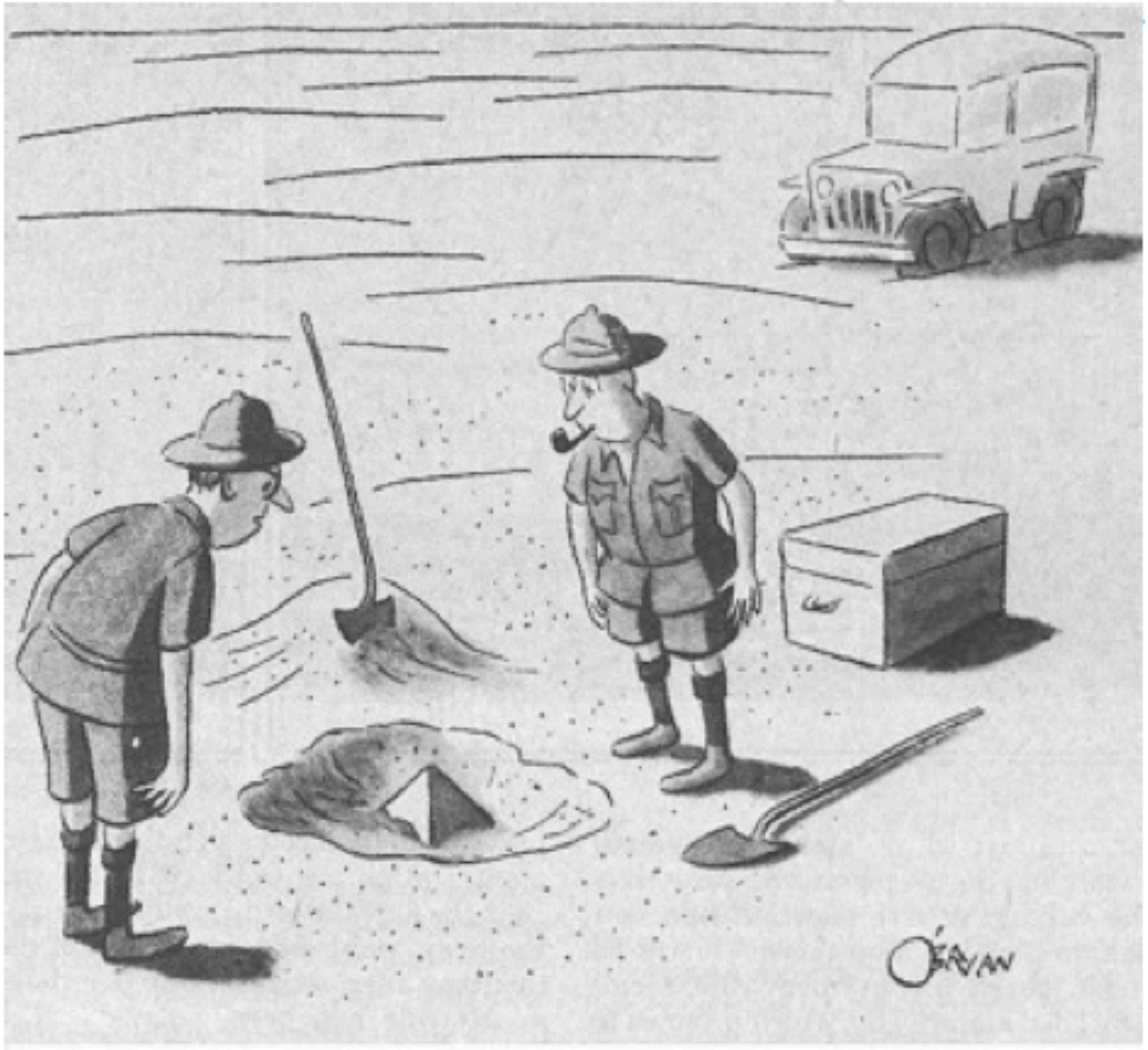
Summary: Interpretation

- By combining a consistent set of inclusive topology searches, it is possible to recover mass limits for SUSY models in general, which are universal i.e. irrespective of the underlying assumptions on sparticle content
  - We have combined four searches from the CMS experiment
  - We have extensively validated our framework against published results
  - We have carried out a comprehensive set of systematic studies and carried out an analysis of the SPS benchmark points, with the first and second generation squarks removed as a further cross-check

- For an LSP mass of approximately 100 GeV, we find that based on the 7 TeV dataset of 2011, the combination of the CMS searches exclude a universal, model independent gluino mass of around 900 GeV and a third-generation squark mass of around 475 GeV
  - These limits weaken to 600 GeV and 400 GeV at higher LSP masses

- Concept of universal limits extremely powerful, many applications
  - Extension to 1st and 2nd generation squark masses
  - Predictions for 2012 dataset
  - Work in progress, to be submitted soon.

Discoveries take time…



"This could be the discovery of the century"

Other slides…

Overall SUSY search strategies

Strategy adopted for initial searches:

- be as inclusive as possible
- target multiple final state signatures
  - attempt to discover New Physics model in variety of searches, dependent on complexity of underlying spectra

Zero lepton	Single lepton	Dilepton: Opposite Sign	Dilepton: Same Sign	Multi leptons	2-photons	Photon + Lepton

Strategy refinement:

- add dedicated searches for different final states
  - especially stops and sbottoms

0-leptons: alphaT

CMS-SUS-12-028_8TeV_11/fb

Inclusive search based on the **alphaT kinematic variable**

Binned in (67 signal regions)

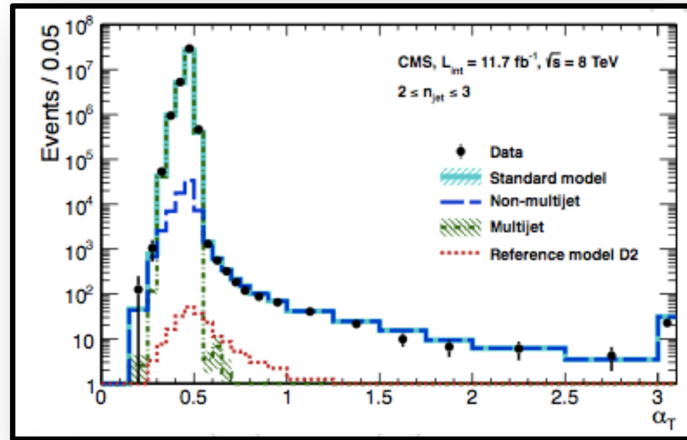
- Number of jets (2-3, >=4)
- Number of b-jets (0,1,2,3,>=4)
- H_T (8 bins from 275 to >=875 GeV)

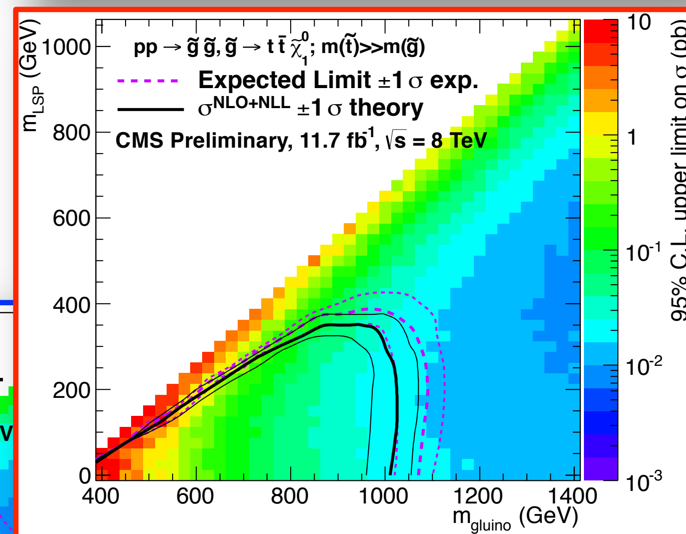
Data driven background estimates from control regions

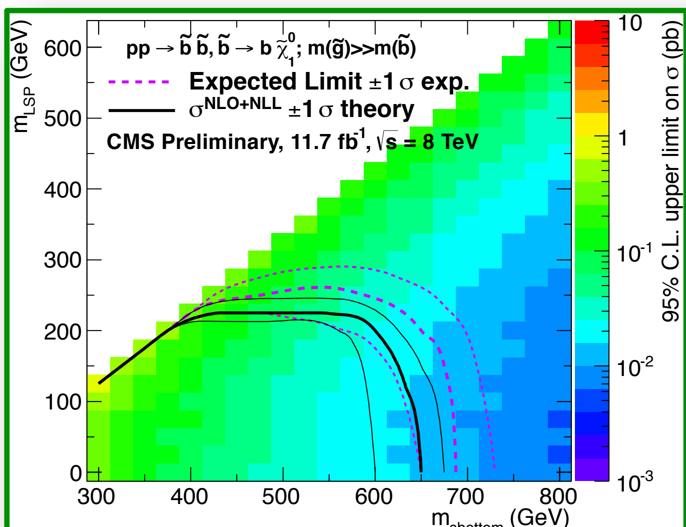
- Major: W+Jets, Z+Jets, ttbar+Jets

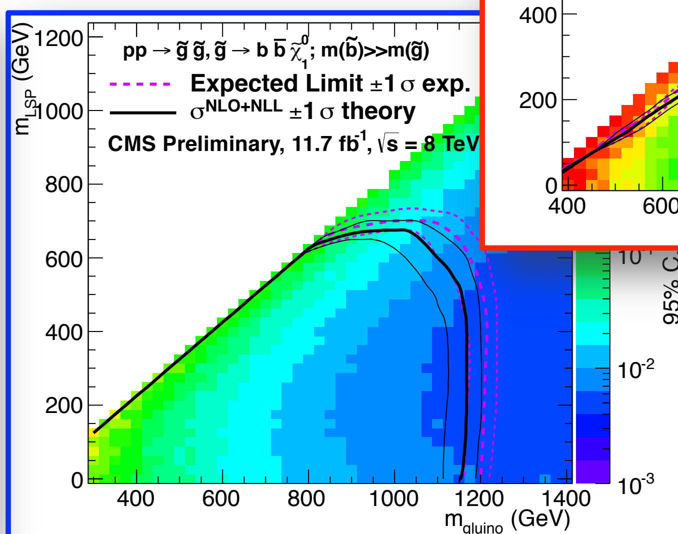
Interpretations in:

- **gluino induced top-squark production**
- **gluino induced bottom-squark production**
- **direct bottom-squark production**
- *more available in documentation*

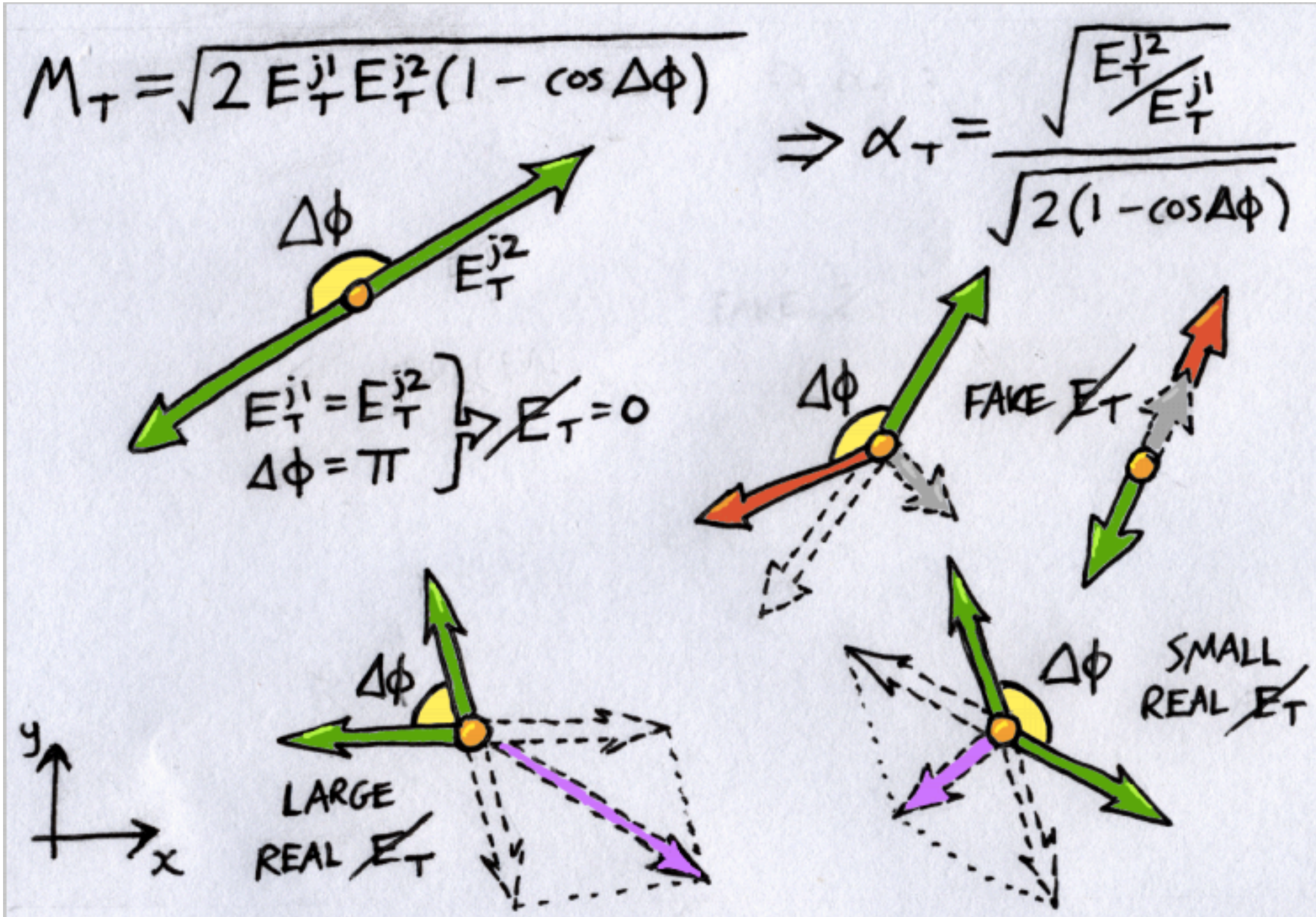








0-leptons: alphaT



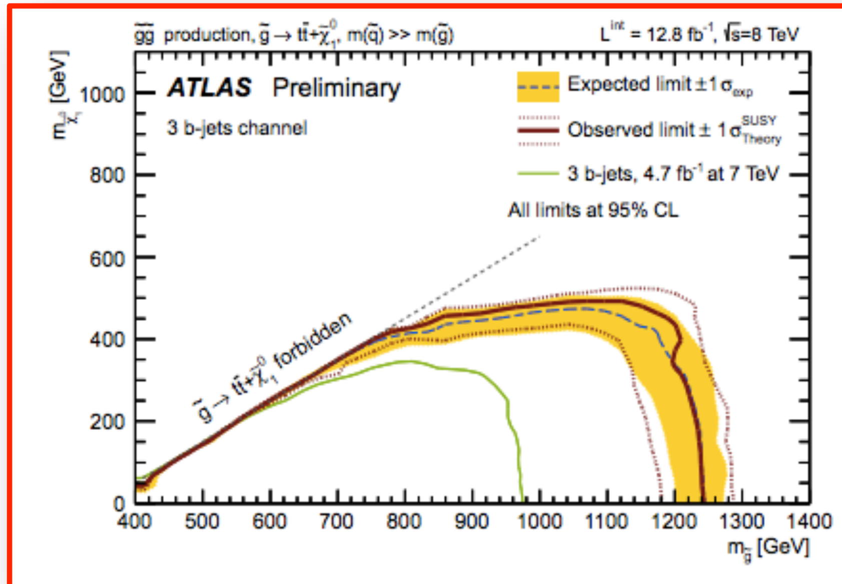
0-leptons: Effective mass

ATLAS-CONF-2012-145_8TeV_12/fb

Dedicated search with at least 3 b-jets
Discriminators:
- Effective mass (at least 900 GeV, 3 bins)
- Number of jets (>=4, >=6)
- DeltaPhi(jets, E_T^{miss}) > 0.4
- E_T^{miss} >= 200 GeV

Data driven background estimates:
- ttbar+jets, multi-jet

Interpretations in
- **gluino induced top-squark production**
- **gluino induced bottom-squark production**



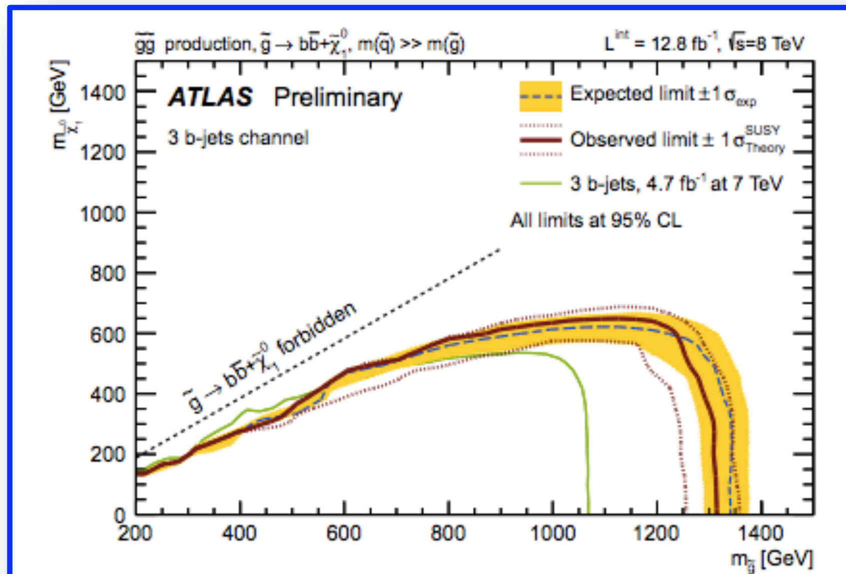


TABLE : *Fitted backgrounds in selected signal regions (SR).*

Signal region	SR4-L	SR6-L
$t\bar{t}$+jets	30 ± 6	12 ± 4
$t\bar{t} + b/b\bar{b}$	8.1 ± 8.3	4.6 ± 5.0
single top	3.5 ± 1.3	0.6 ± 0.3
$t\bar{t} + W/Z$	1.4 ± 0.8	0.8 ± 0.4
W/Z	2.6 ± 1.9	0.1 ± 0.1
Total background	46 ± 10	18 ± 6
Observed	38	20

0-leptons: H_T vs E_T^{miss} vs b-tag fit

CMS-SUS-12-024_8TeV_19/fb

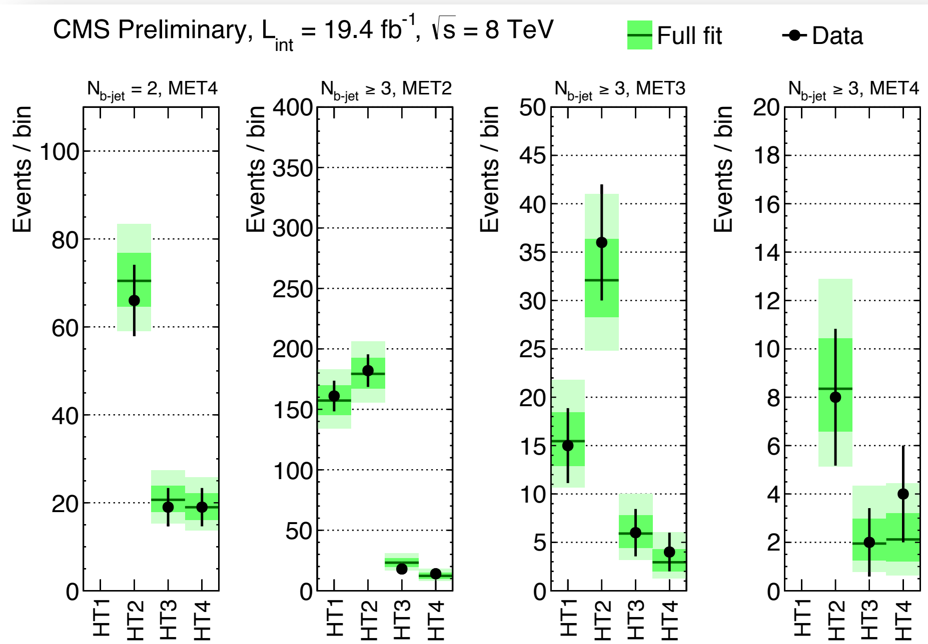
Inclusive search with >=3 jets

Binned in (48 Signal Regions)

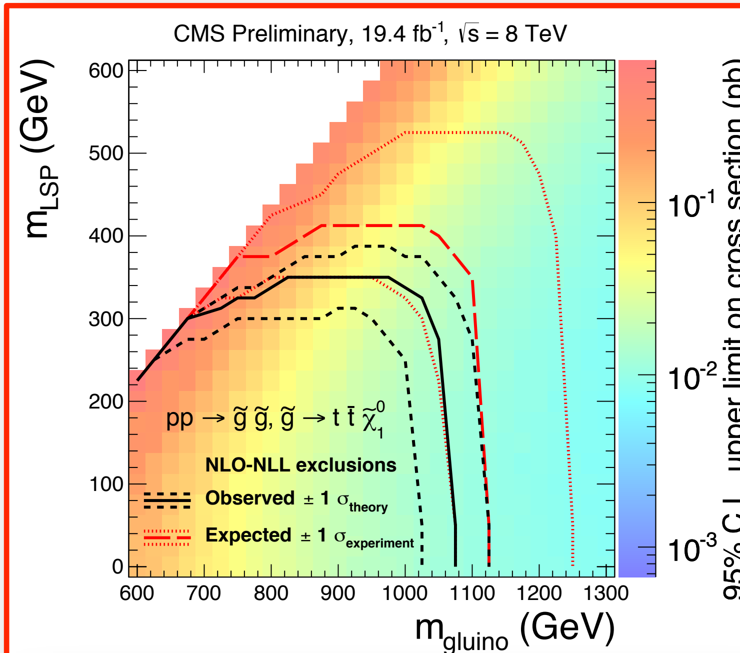
- Number of b-jets (1,2,>=3)
- H_T (4 bins from 400 to >=1000 GeV)
- E_T^{miss} (4 bins from 125 to >=350 GeV)

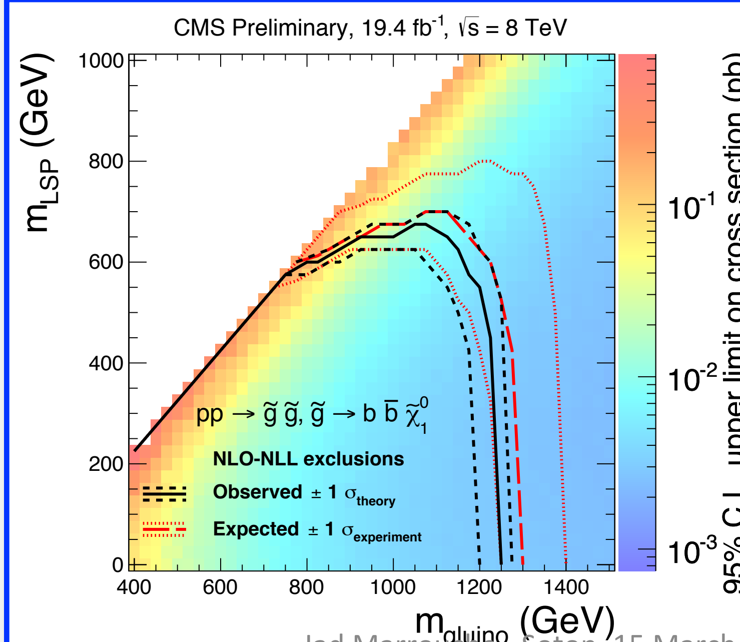
Interpretations in

- gluino induced top-squark production
- gluino induced bottom-squark production



14 most sensitive bins for interpretation





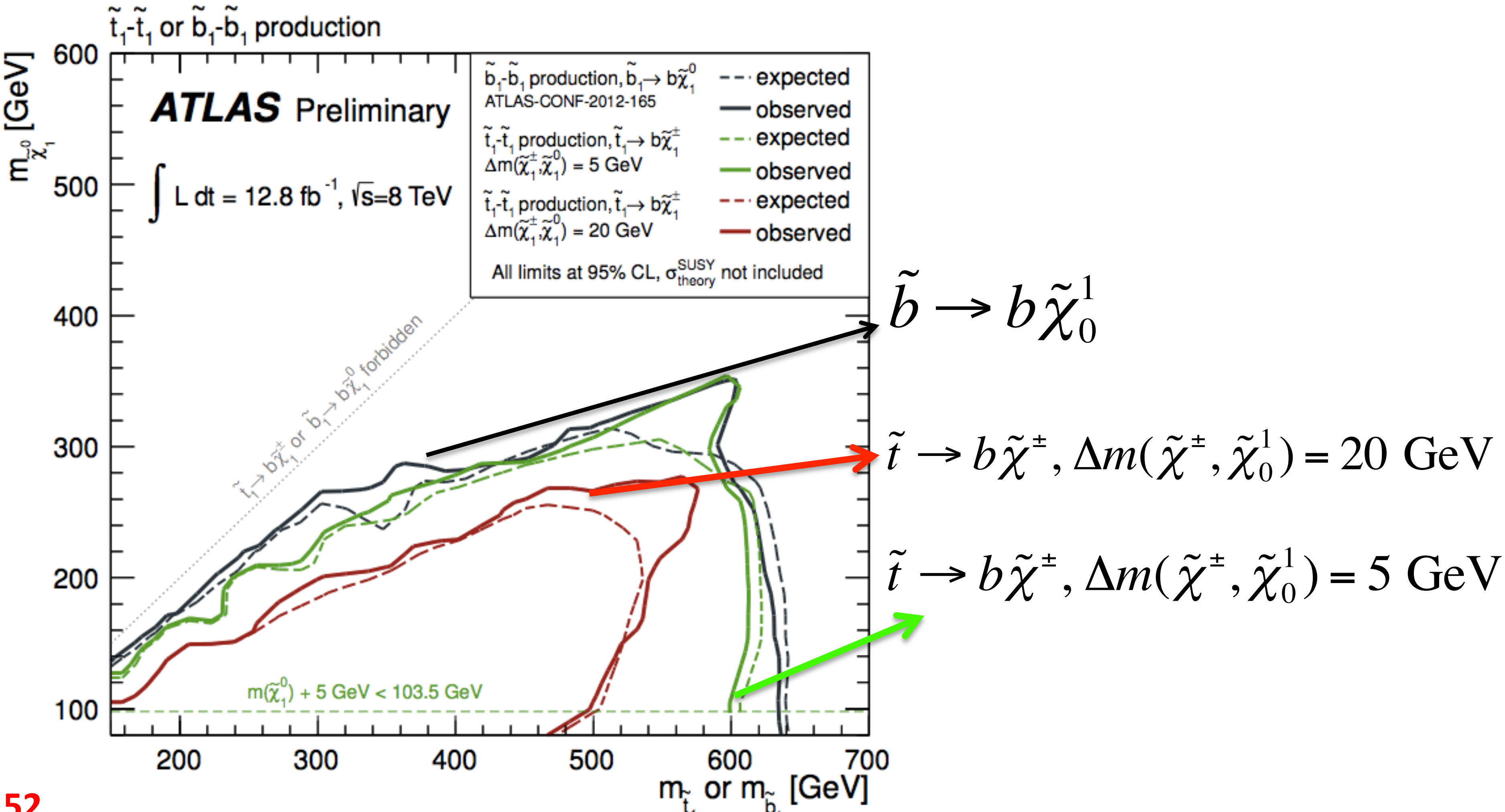
0-leptons: bb+MET

ATLAS-CONF-2012-165 & 2013-001_8TeV_13/fb

Search with exactly 2 b-jets and MET or exactly 3 jets where leading jet not tagged, sub-leading 2 are. Targets direct sbottom production

Discriminators: ETmiss, Effective mass, DeltaPhi

Interpretations shown for direct sbottom production (neutralino) and stop (chargino)



1-lepton: Dedicated stop search

ATLAS-CONF-2012-166_8TeV_13/fb

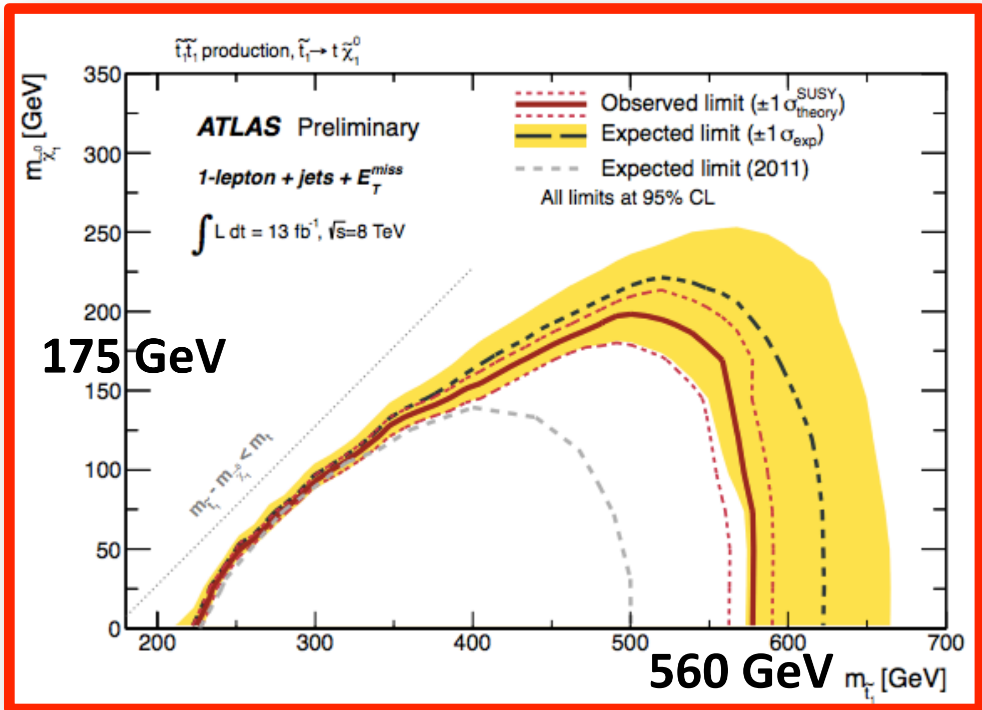
Targeting direct top squark production:
- an isolated electron or muon
- at least 4 jets
- at least 1 b-jet
- E_T^{miss} at least 150 GeV

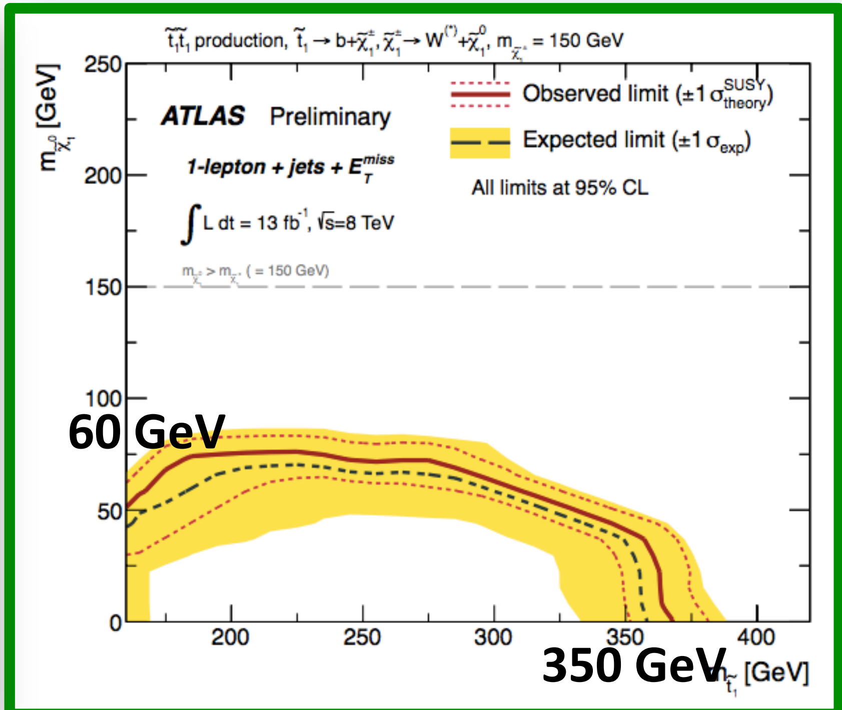
6 signal regions defined by various binning in
- transverse mass
- two variants of kinematic variable mT2

Main backgrounds: di-leptonic ttbar, W+jets

Interpretations shown
- **direct top-squark pair production, decay via neutralino**
- **direct top-squark pair production, decay via chargino with mass = 150 GeV**

CMS search details in backup





1-lepton: Dedicated stop search

CMS-SUS-12-023_8TeV_10/fb

Targeting direct top squark production:

- an isolated electron or muon
- at least 4 jets
- at least 1 b-jet

7 signal regions defined by binning:

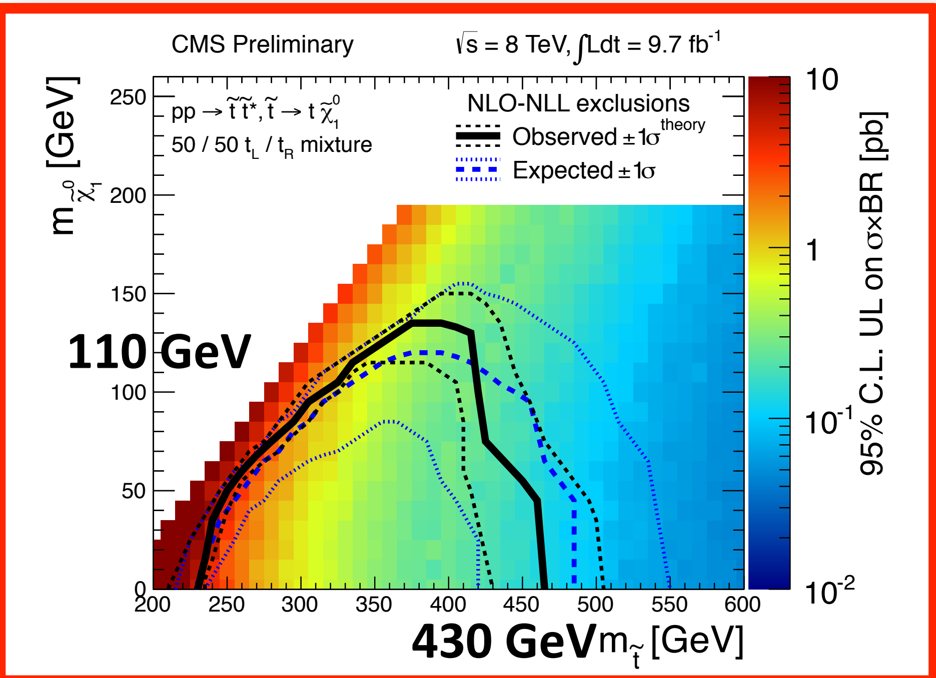
- **E_T^{miss}** (>100 GeV)
- transverse mass (>120 GeV)

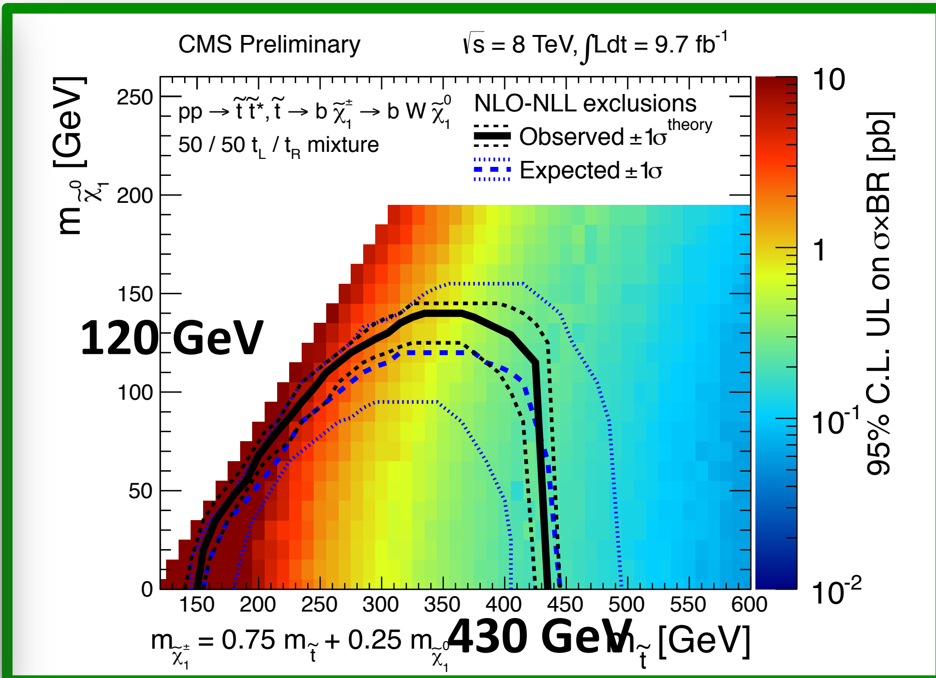
Main background: ttbar (fully and semi-leptonic)

- Estimated from simulation, corrected and validated by data control samples

Interpretations shown

- **direct top-squark pair production, decay via neutralino**
- **direct top-squark pair production, decay via chargino**





2-leptons (Opposite Sign)

Search requiring

- 2 isolated opposite-sign electrons or muons

Discriminators

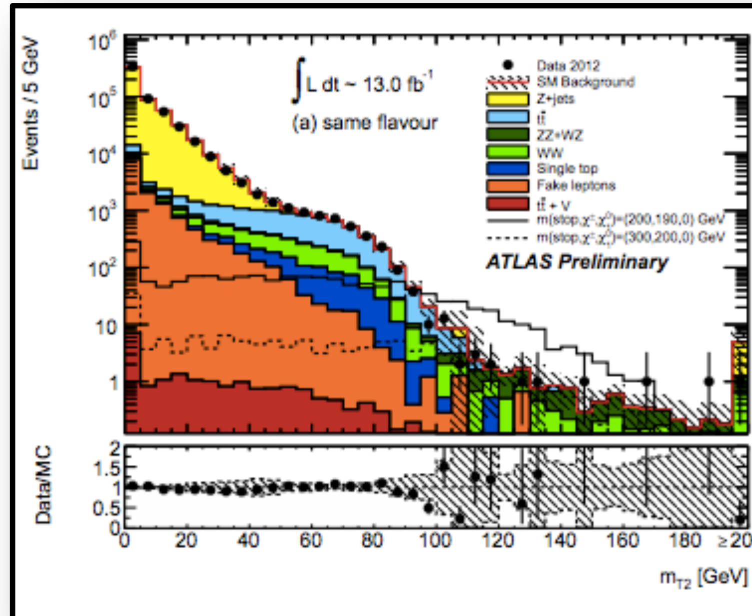
- **mT2**
- Boost vector = vec(ETmiss+ pT(lep1)+ pT(lep2))

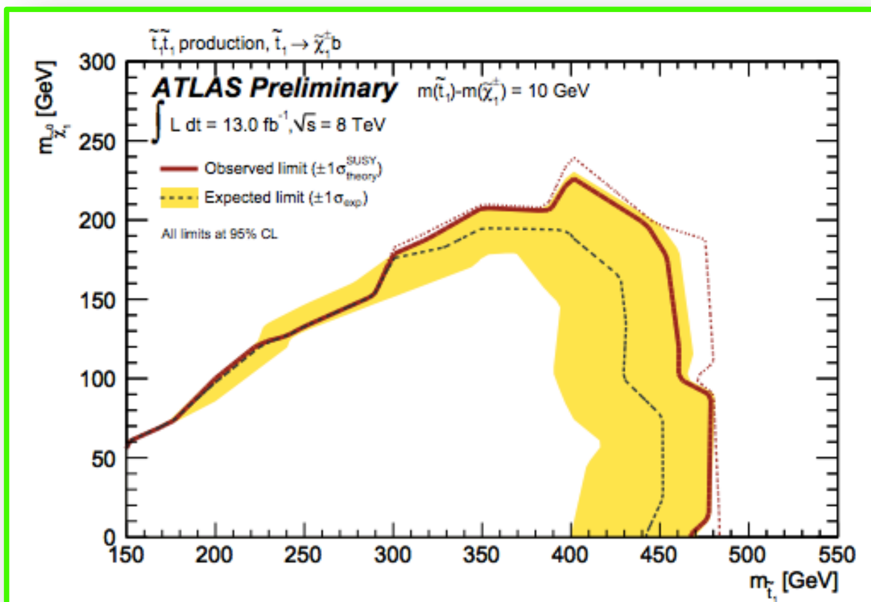
Main Backgrounds:

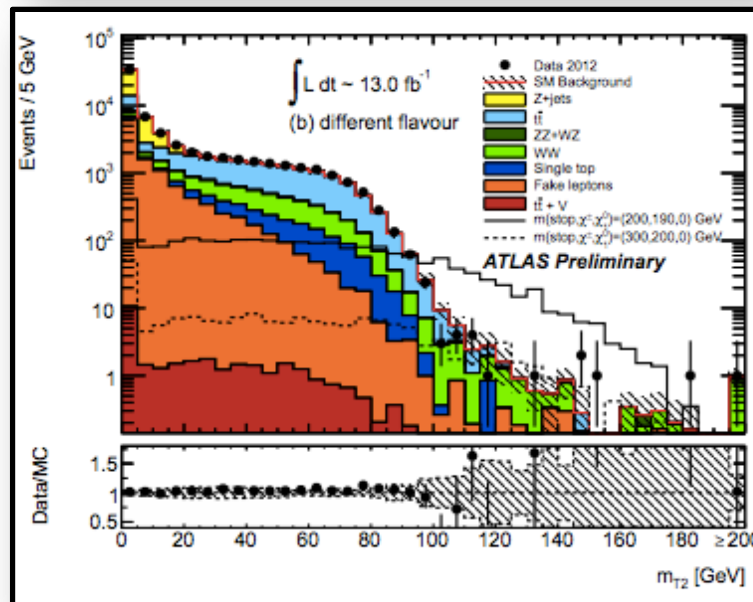
- top production, diboson (data-driven)

Interpretations in

- **direct top-squark production, decay via chargino**
- *more available in documentation*







2-leptons (Same Sign)

CMS-SUS-12-017_8TeV_11/fb

arXiv:1212.6194 -- accepted by JHEP

Inclusive search requiring

- 2 isolated same-sign electrons or muons
- at least 2 b-jets

8 Signal Regions with

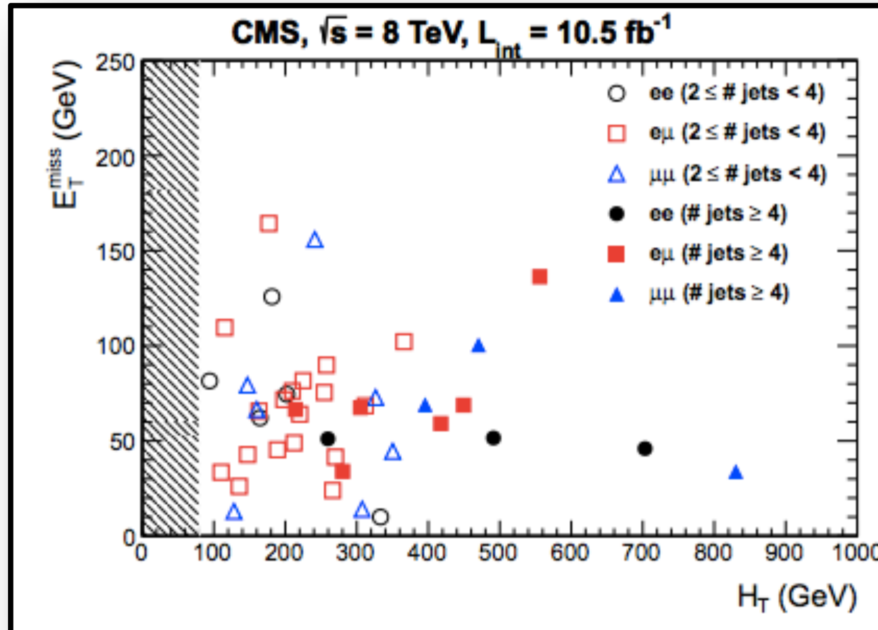
- **HT range from >80 to >320**
- **E_T^{miss} range from >0 to >120**

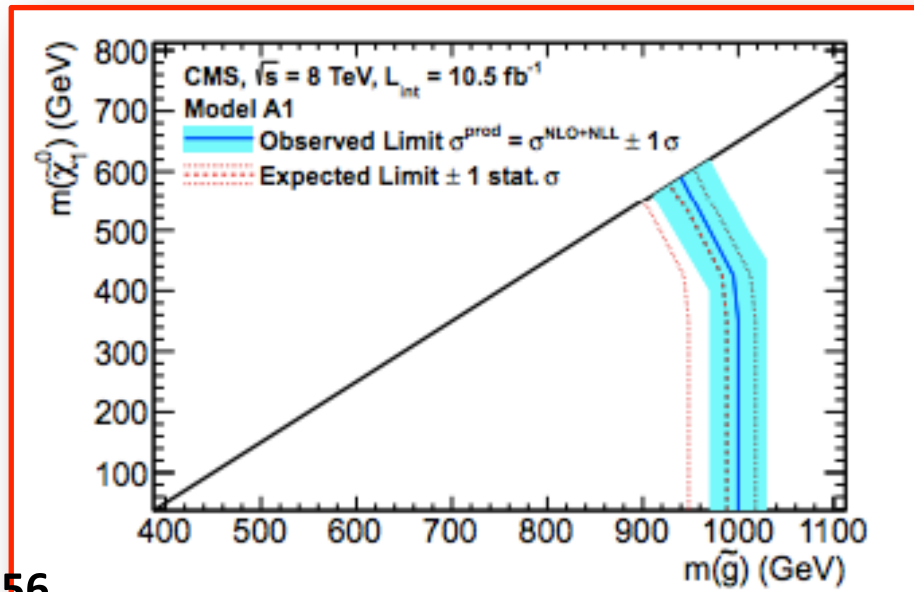
Backgrounds:

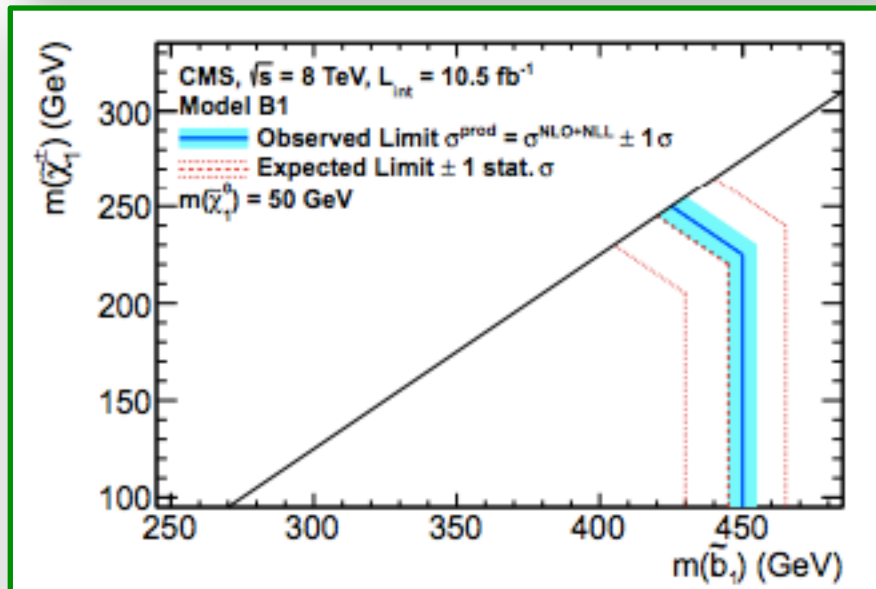
- rare SM decays, fake leptons, charge flips

Interpretations in

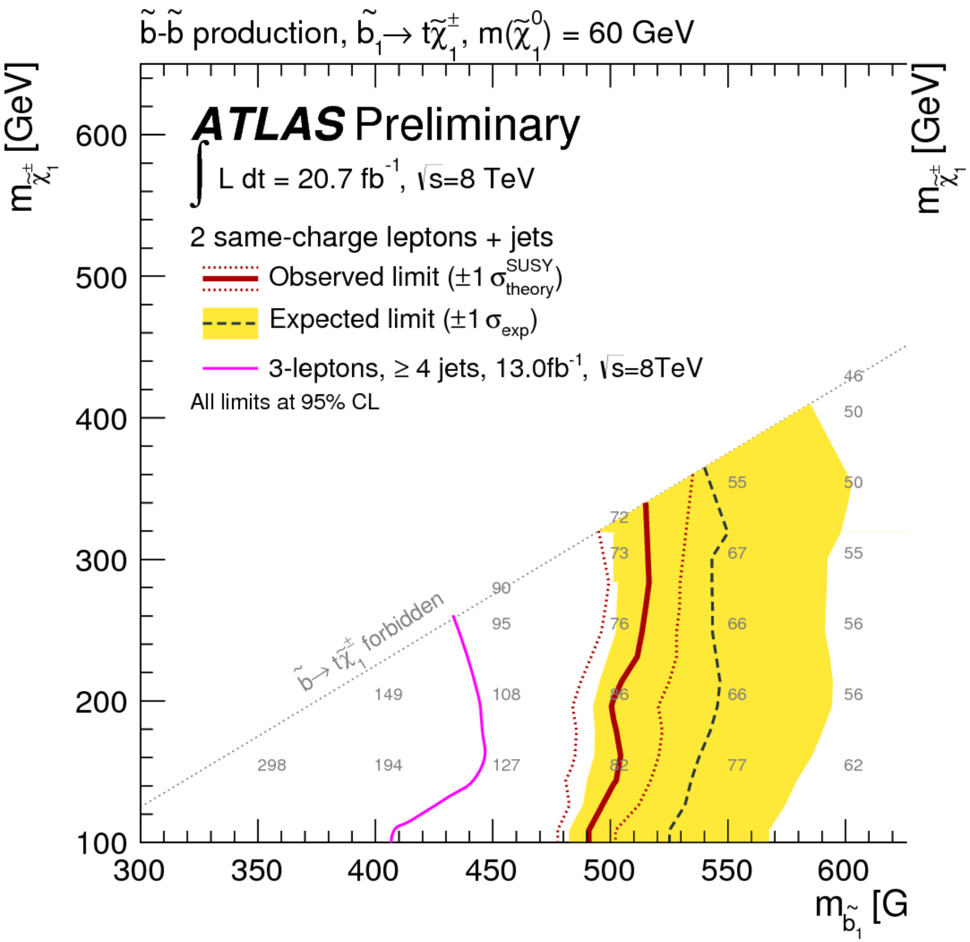
- **gluino induced top-squark production**
- **direct bottom-squark, decay via chargino**
- *more available in documentation*

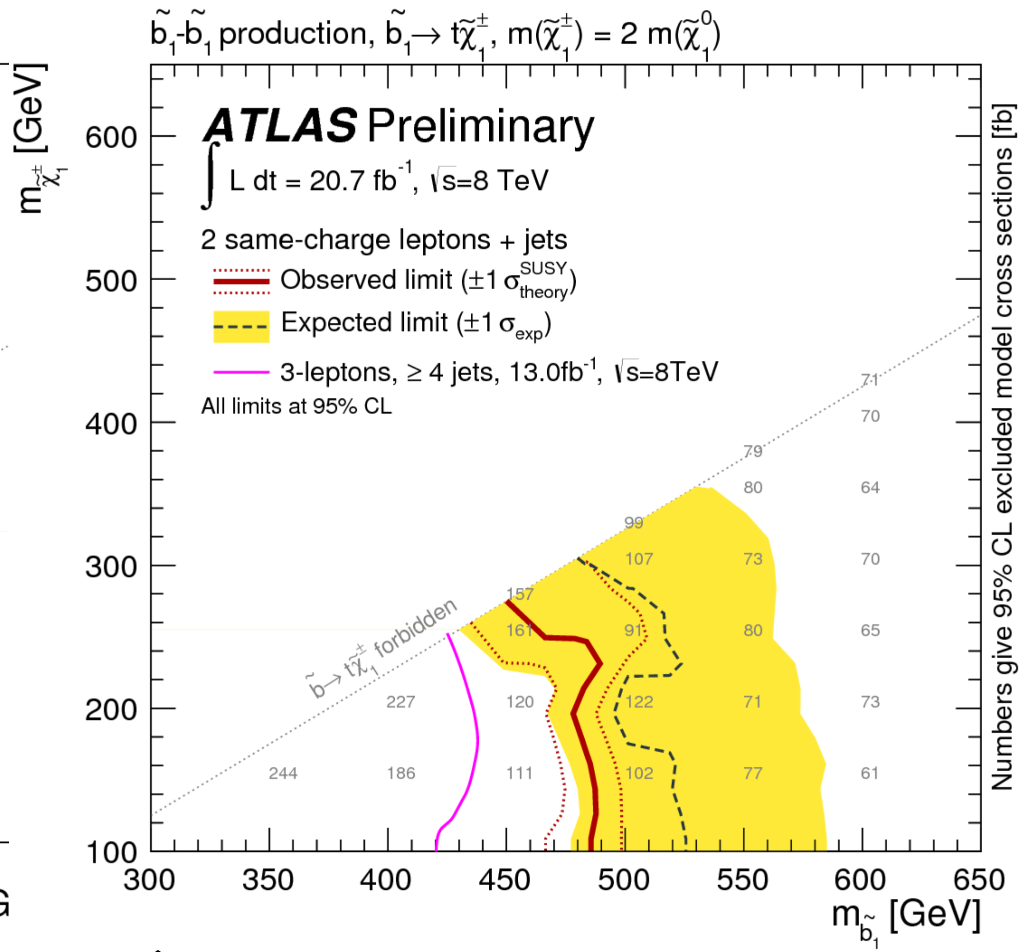






2-leptons (Same Sign)

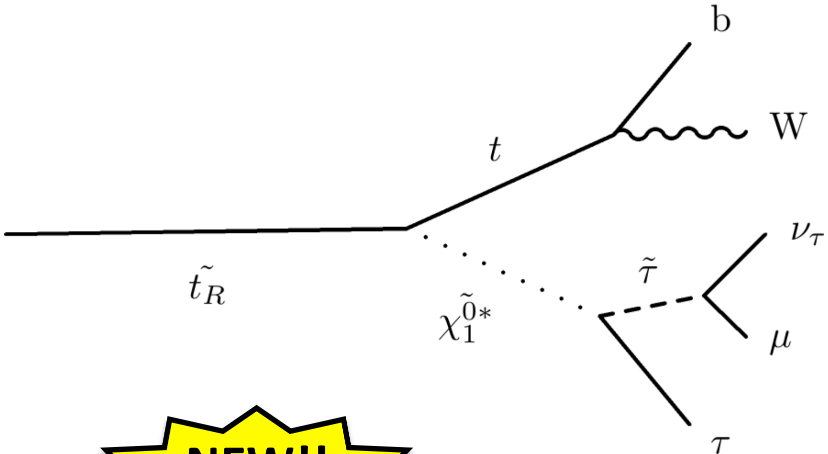


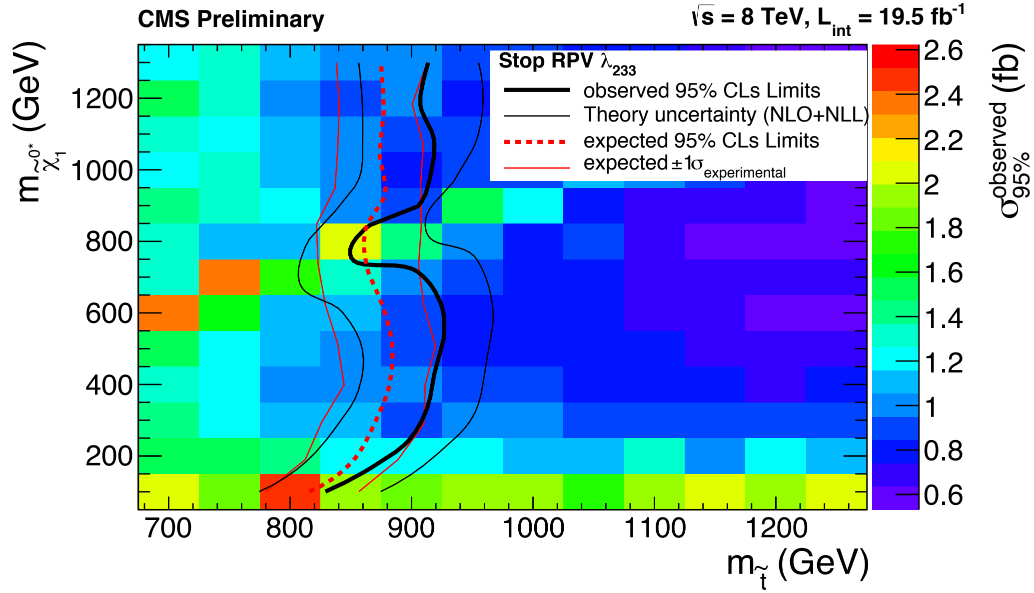


NEW!!
20fb^{-1}

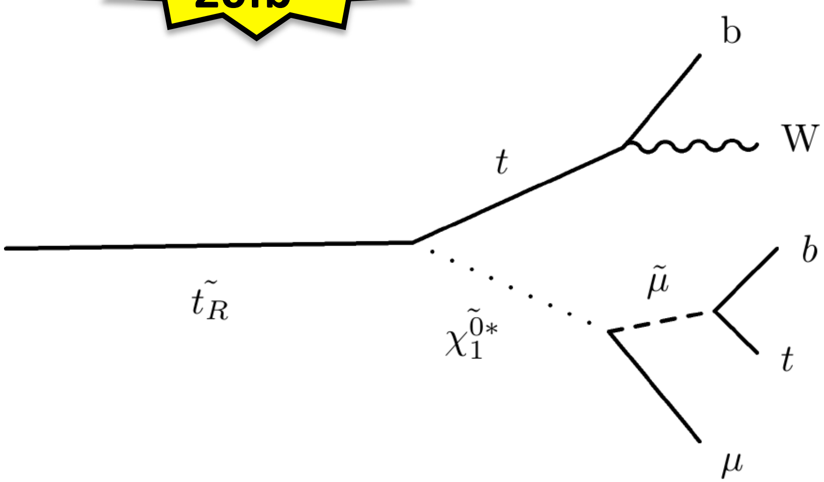
R-Parity Violating Stop Search

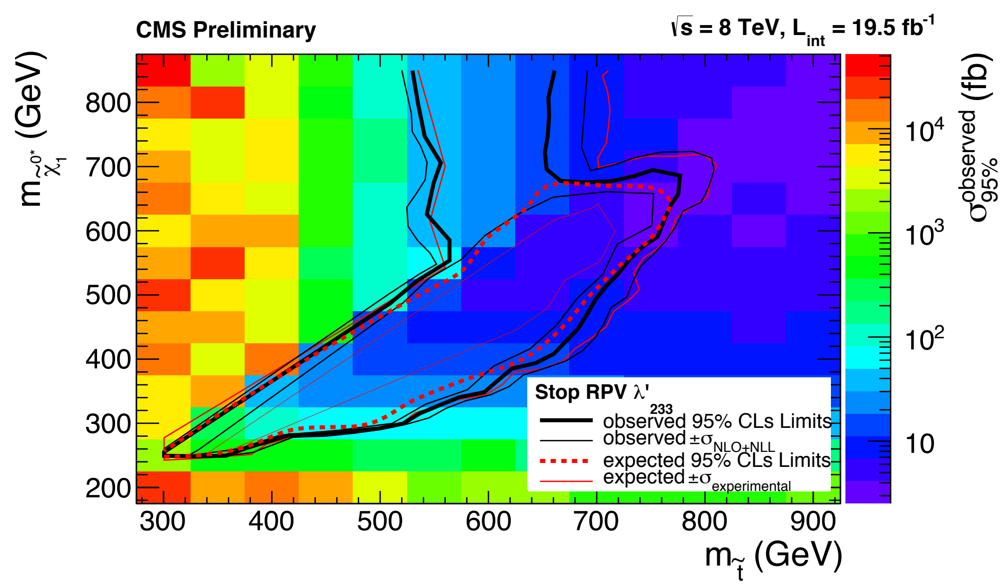
CMS-SUS-13-003_8TeV_19/fb





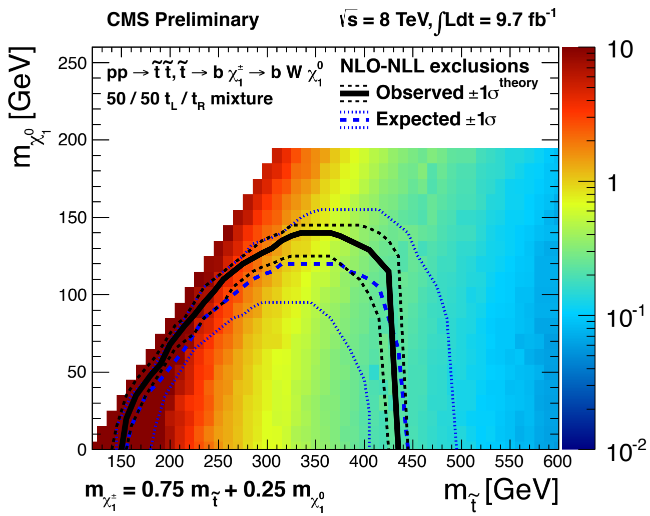
NEW!!
20fb^{-1}



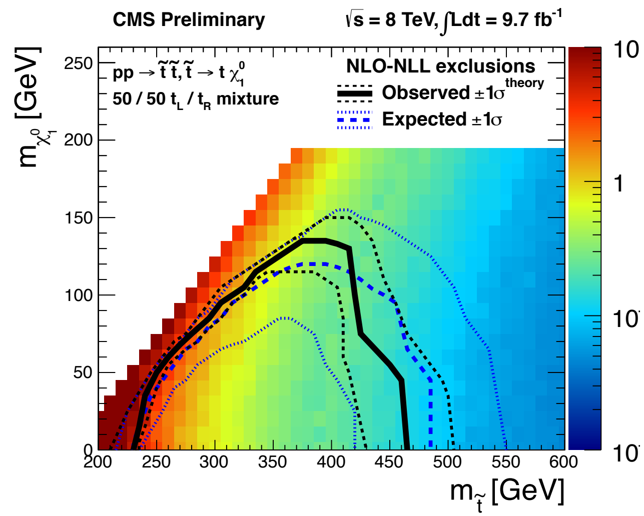


1ℓ top squark: Comparison with ATLAS

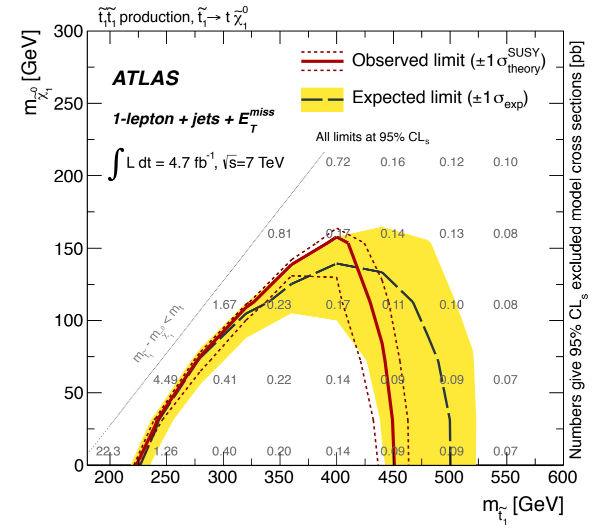
$\tilde{t} \to b\chi^{\pm}$ x = 0.75



$\tilde{t} \to t\chi^{0}$



$\tilde{t} \to t\chi^{0}$



- When correcting for luminosity and √s, the ATLAS limit covers more of the $\tilde{t} \to t\,\chi^0$ space for two reasons:
  - 1) Different signal model: CMS signal model has **unpolarized tops** from $\tilde{t} \to t\,\chi^0$. ATLAS signal model has **top quarks which are mostly right-handed**. This choice increases the large lepton p_T and M_T(ℓ,MET) acceptance because it causes the lepton to be emitted preferentially parallel to the top boost. **We estimate the size of this effect to be ~25%**.
  - 2) Tuned kinematical requirements: The most important one appears to be the **hadronic top reconstruction**. This is not currently implemented in the CMS analysis in order to **maintain sensitivity to both the $\tilde{t} \to t\,\chi^0$ and $\tilde{t} \to b\,\chi^{\pm}$ decay modes**.

Top Polarization

arxiv: 0811.1024

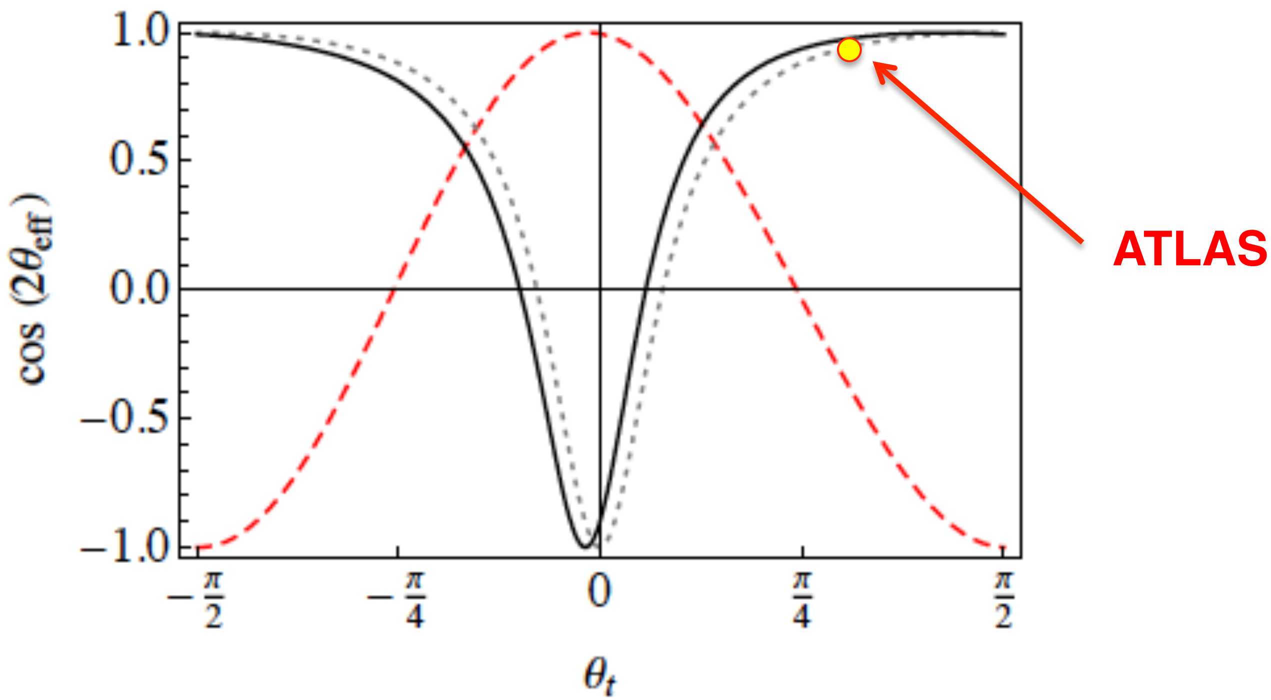
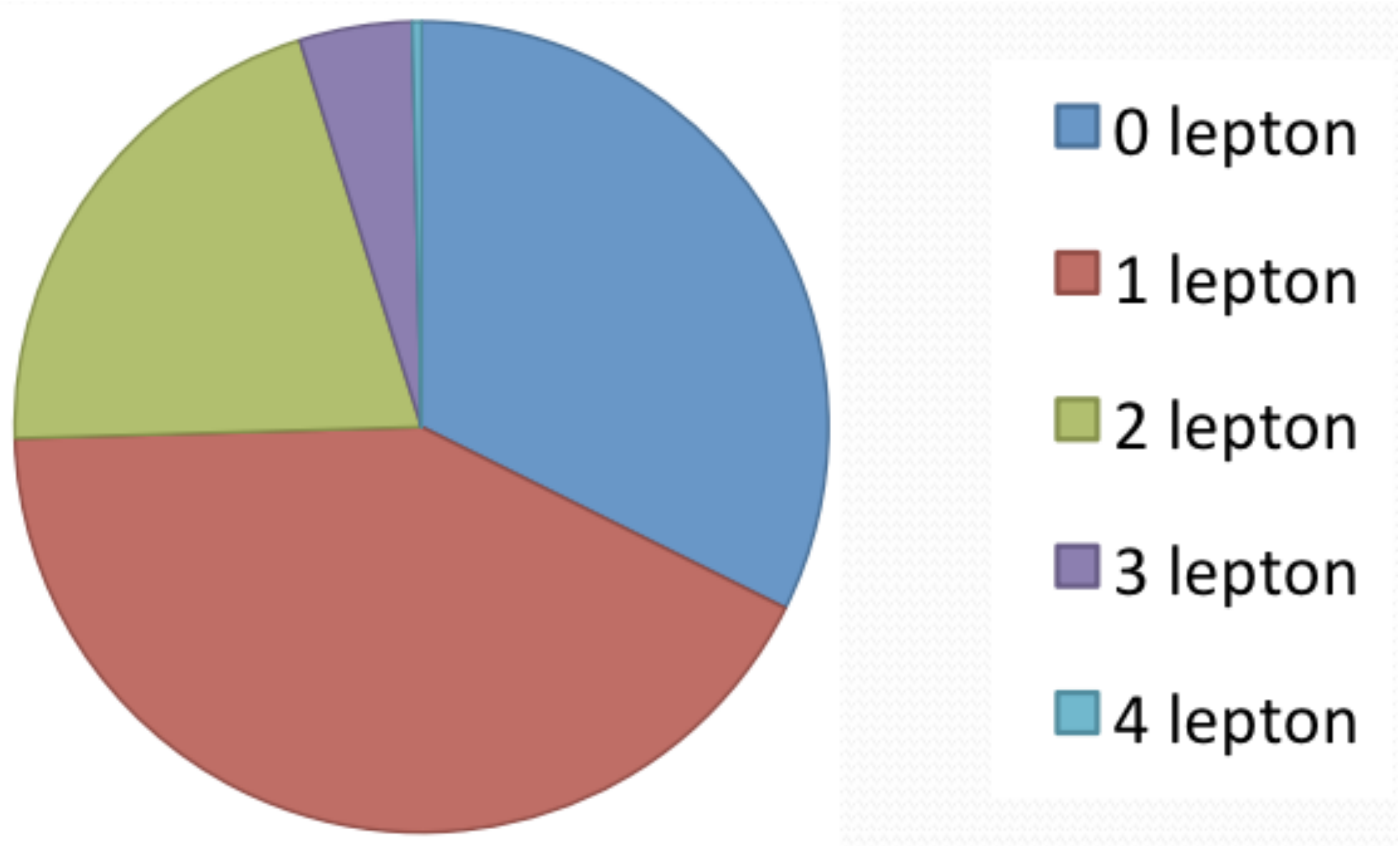
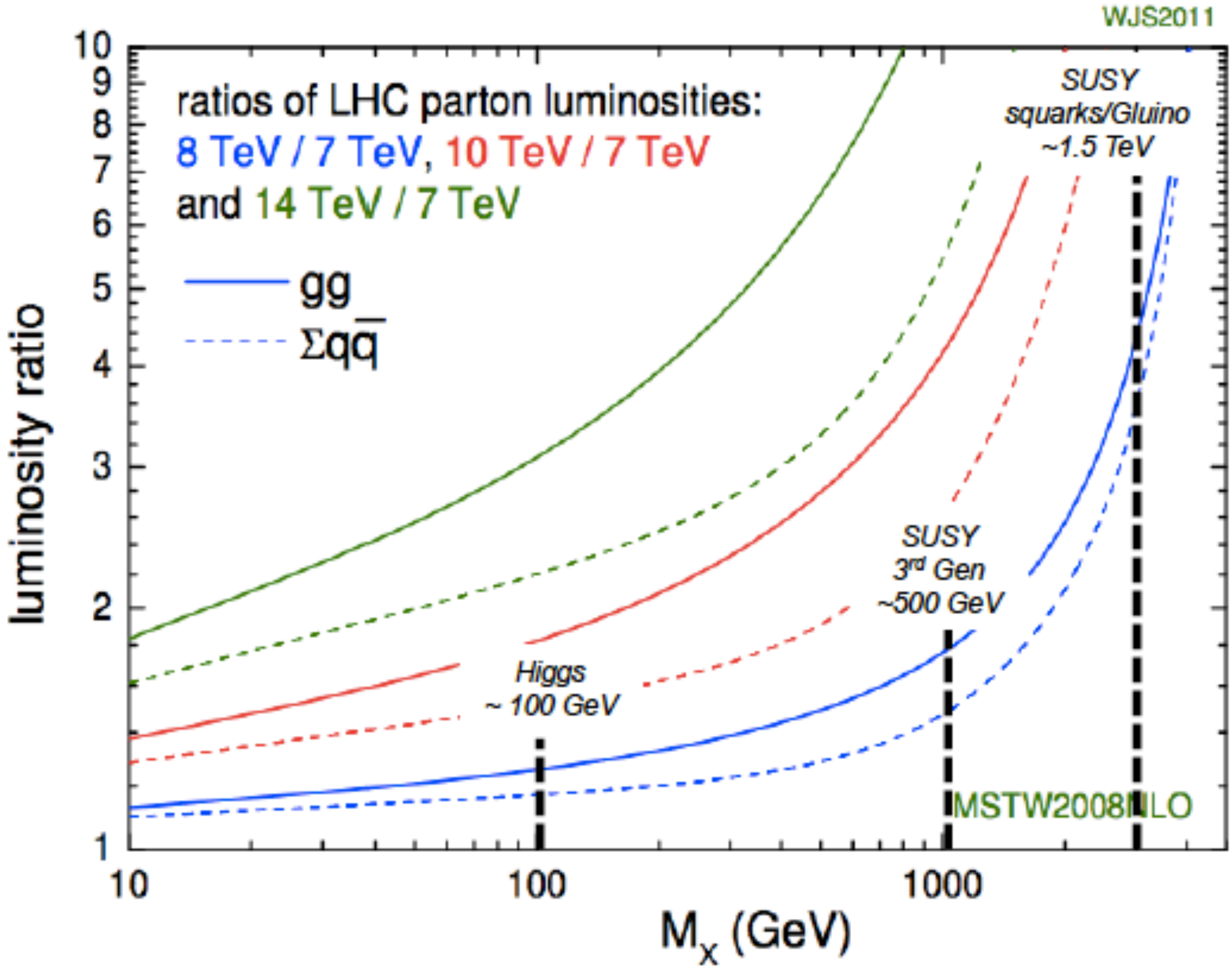


Figure 9: $\cos 2\theta_{\rm eff}$ vs. the stop mixing angle θ for three different neutralino mixing matrices. The solid (black) curve is our benchmark scenario, the dotted (gray) curve corresponds to the case where the lightest neutralino is pure bino and the dashed (red) curve corresponds to pure higgsino.

In the limit of zero LSP mass, the parameter $\cos 2\theta_{eff}$ is the top quark polarization.
Atlas uses $\theta_t = \pi/3.2$; At m(LSP)=0 the top in the Atlas MC is almost fully polarized

4W final state





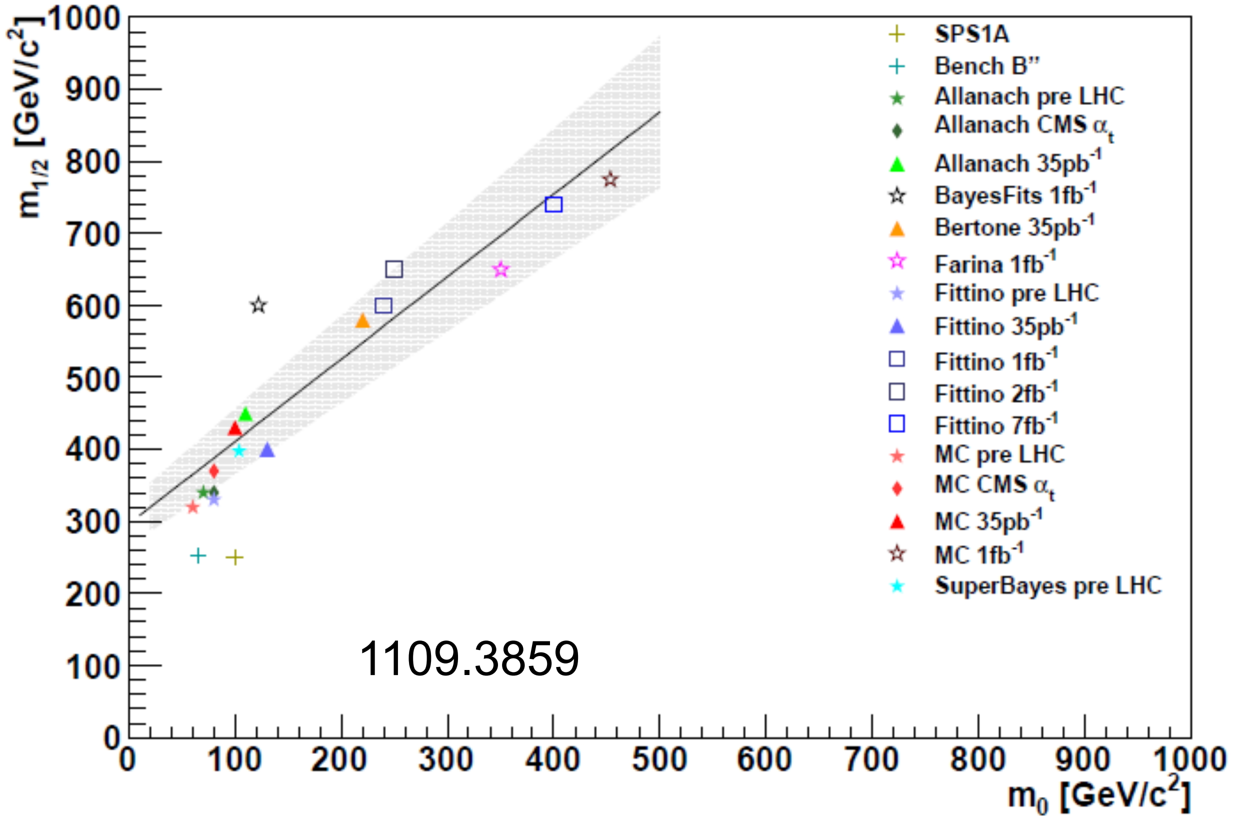
WJS2011
ratios of LHC parton luminosities:
8 TeV / 7 TeV, 10 TeV / 7 TeV
and 14 TeV / 7 TeV
gg
Σqq̄
SUSY
squarks/Gluino
~1.5 TeV
SUSY
3rd Gen
~500 GeV
Higgs
~ 100 GeV
MSTW2008NLO
luminosity ratio
1
2
3
4
5
6
7
8
9
10
10
100
1000
M_X (GeV)

CMSSM Global Fitting

Recipe:
- Combine measurements
- Compare with predictions
- Constrain the parameters
    - or exclude the model!

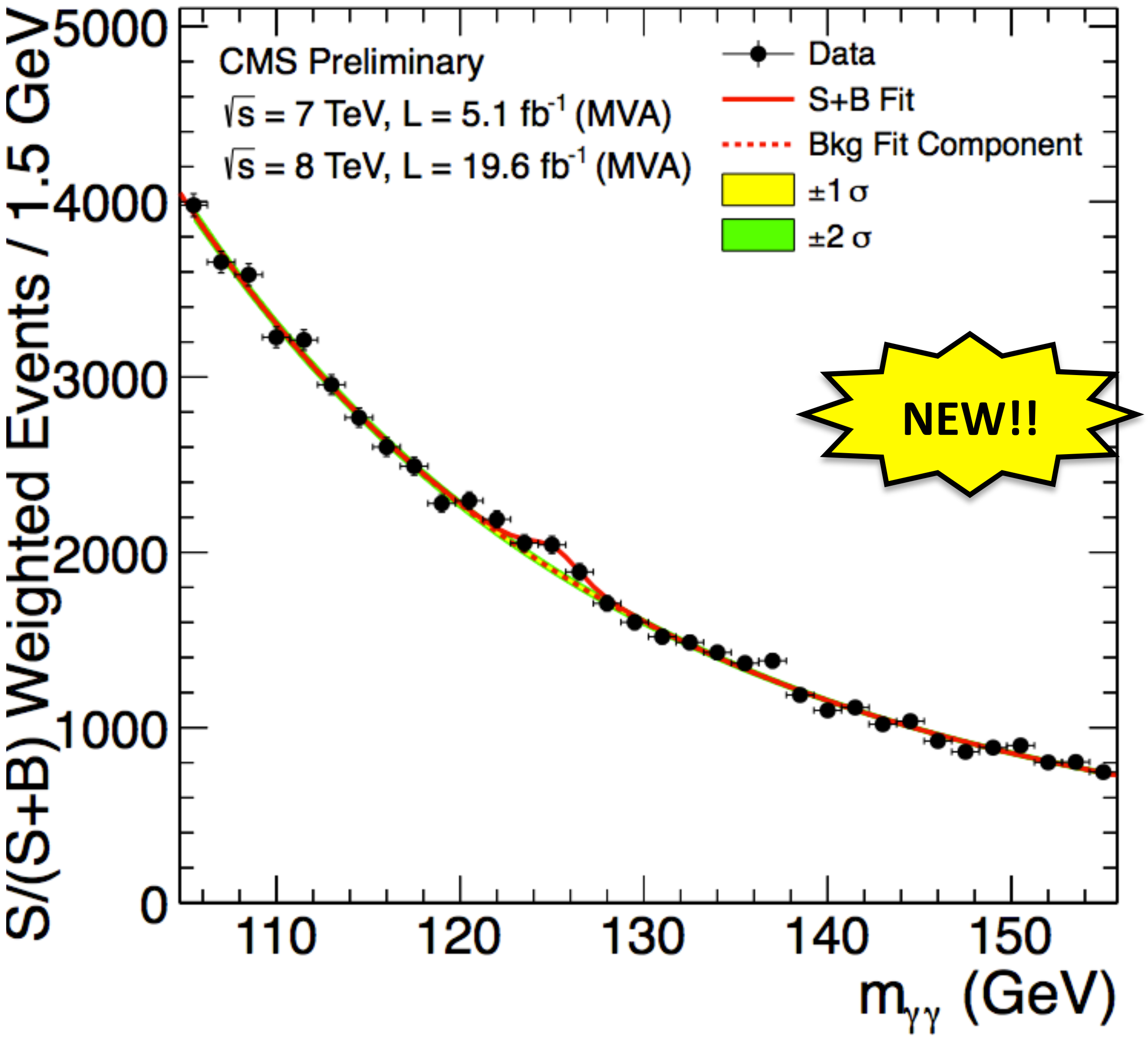
Ingredients:
- Accurate set of predictions
- Consistent set of measurements

Trend of best-fit points

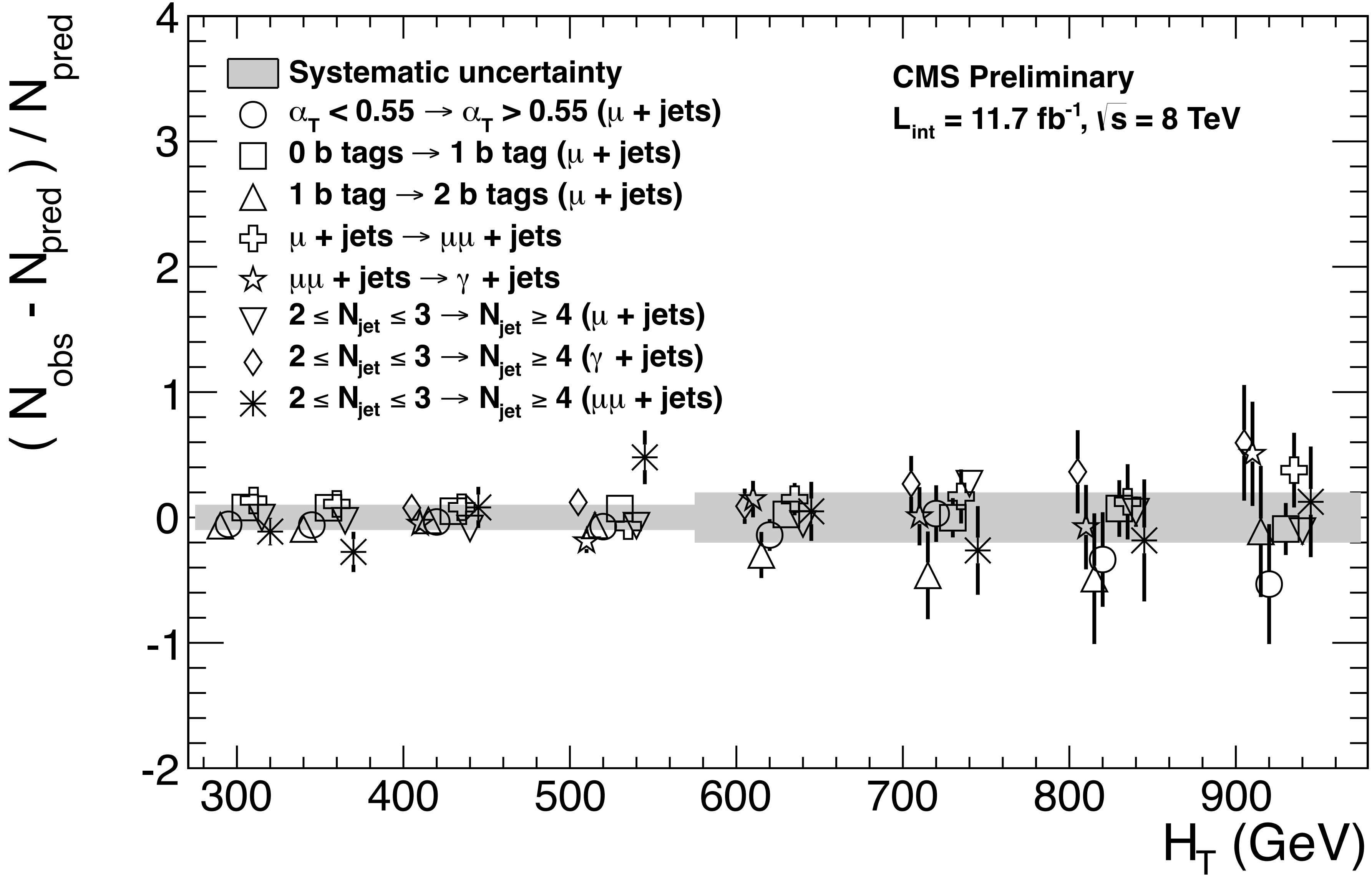


- Many fitting groups, many different approaches
  - Bayesian vs Frequentist
  - Basic conclusion: direct searches pushing masses higher

Look what we found…



alphaT: systematic uncertainties for N_{jet}=2,3



Validation of searches