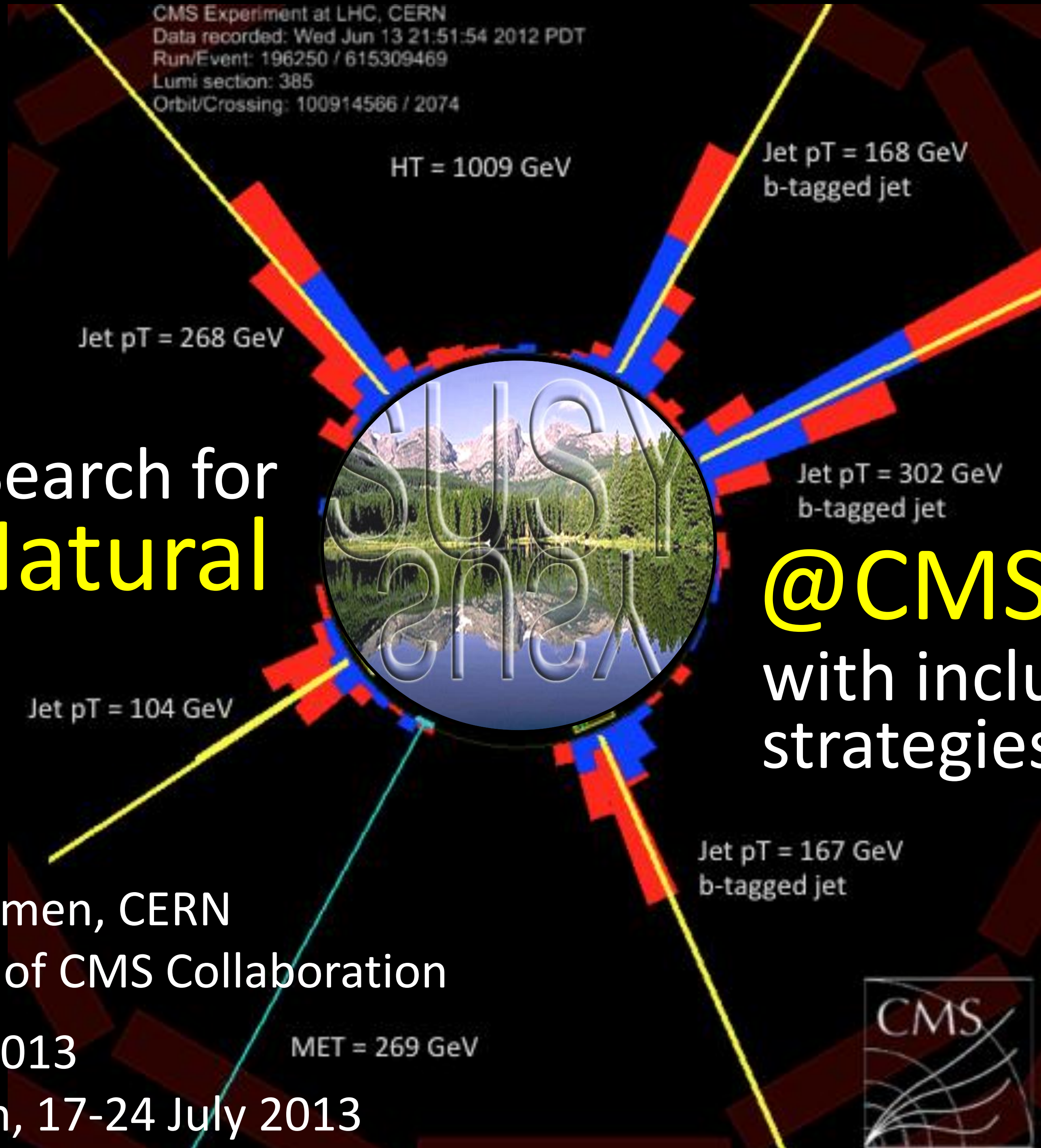
Search for Natural SUSY @CMS with inclusive strategies

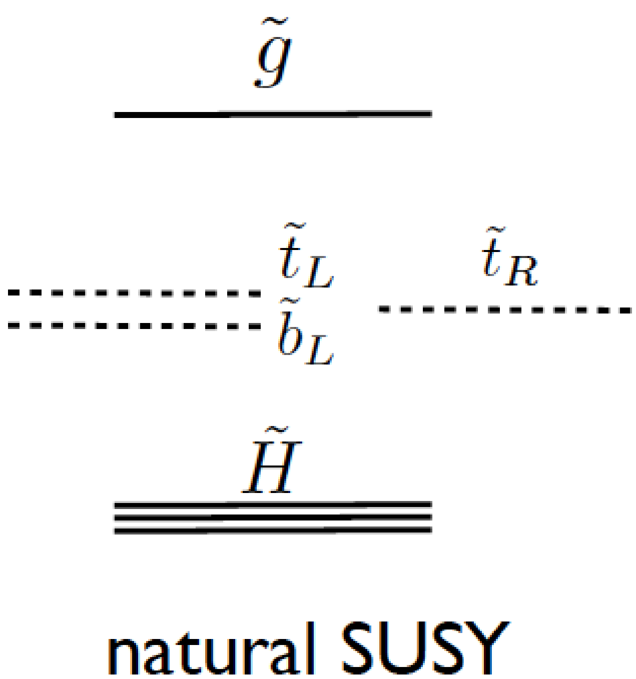


Sezen Sekmen, CERN
on behalf of CMS Collaboration

EPS HEP 2013
Stockholm, 17-24 July 2013

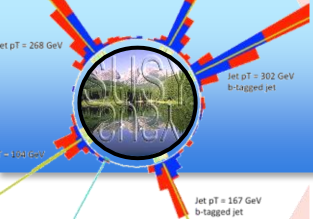
Natural SUSY

Requirement of natural EW symmetry breaking imposes constraints on the SUSY mass spectrum. Sparticles contributing to EWSB scale definition need to be light to avoid fine tuning.



Papucci, Rudermann, Weiler, JHEP 1209 (2012) 035

- Leading contribution to EW scale comes from Higgsinos → ≤ few hundred GeV
- Stops contribute to Higgs mass via 1-loop corrections → ≤ few hundred GeV
- Sbottom left is tied to stop left → ≤ few hundred GeV.
- Gluinos contribute to Higgs mass via 2-loop corrections → ≤ few TeV
- Rest of the spectrum can be decoupled / heavy.



CMS in search of natural SUSY

List of CMS SUSY analyses looking for sparticles accessible in natural SUSY

In this talk (first two rows)

Final state	variables	sparticles	L (fb^{-1})	Reference
jets, b-jets, E_T^{miss}	H_T, α_T	$\tilde{g}$, $\tilde{t}$, $\tilde{b}$	11.7	arXiv:1303.2985
jets, b-jets, E_T^{miss}	H_T, $\Delta\hat{\phi}_{min}$	$\tilde{g}$, pMSSM	19.4	arXiv:1305.2390
Single ℓ, jets, E_T^{miss}	m_T	$\tilde{t}$	19.5	CMS-SUS-13-011
Single ℓ, jets, b-jets, E_T^{miss}	–	$\tilde{g}$	19.4	CMS-SUS-13-007
SS 2ℓ, bjets, E_T^{miss}	H_T	$\tilde{g}$, $\tilde{b}$	10.5	arXiv:1212.6194
3ℓ, b jets, E_T^{miss}	H_T	$\tilde{g}$, $\tilde{b}$	19.5	CMS-SUS-13-008

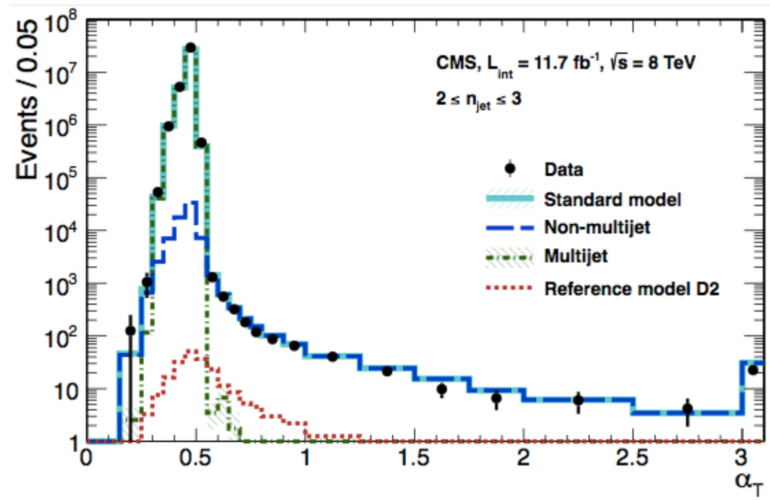
For more details, see the public CMS SUSY results twiki:
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

Jets, b-jets, E_T^{miss} with H_T, α_T (8 TeV, 11.7 fb^{-1}) Introduction

Uses the α_T variable as a discriminator between events with genuine and misreconstructed E_T^{miss}.

$$\alpha_T = E^{j_2}/M_T$$

Generalize to ≥2 jets by constructing a pseudo dijet pair. Choose the combination minimizing ΔH_T between the two pseudojets.



Event selection:

- 1 primary vertex
- ≥2 jets (p_T > 50 GeV, |η| < 3)
- jet1, jet2 p_T > 100 GeV
- No non-identified jets with p_T > 50 GeV, |η| < 3
- No isolated μ/e/τ/γ
- α_T > 0.55 (for the signal region)

Looks for signal excess in a 3D space defined by

- Jet multiplicity (2-3, >3): Discriminate among sq-sq, sq-gl, gl-gl final states
- b-jet multiplicity (0, 1, 2, 3, >3): enhance sensitivity to the 3rd generation
- H_T (8 bins): probe models with a large mass splitting range

Jets, b-jets, E_T^{miss} with H_T, α_T (8 TeV, 11.7 fb^{-1})
Non-multijet background estimation

- Non-multijet BG (tt+jets, W(→lν, τν)+jets, Z(→νν)+jets): used control samples with negligible multijet BG and signal contamination (μ+jets, μμ+jets, γ+jets):

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

predicted BG in the signal sample

transfer function derived using Monte Carlo

observed data in the control sample

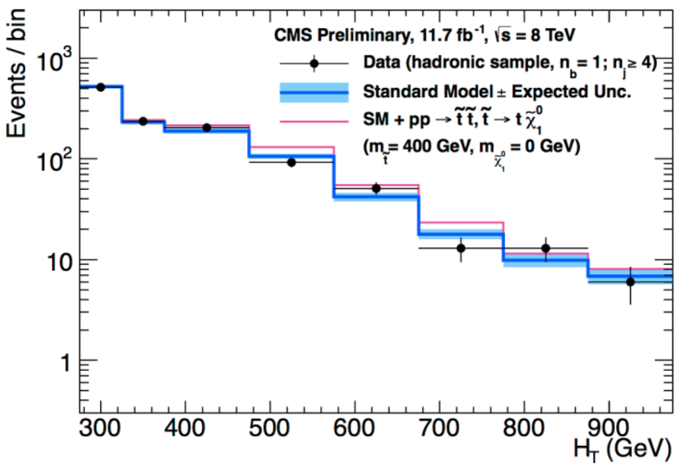
- Multijet BG estimated by exploiting the H_T dependence of the ratio

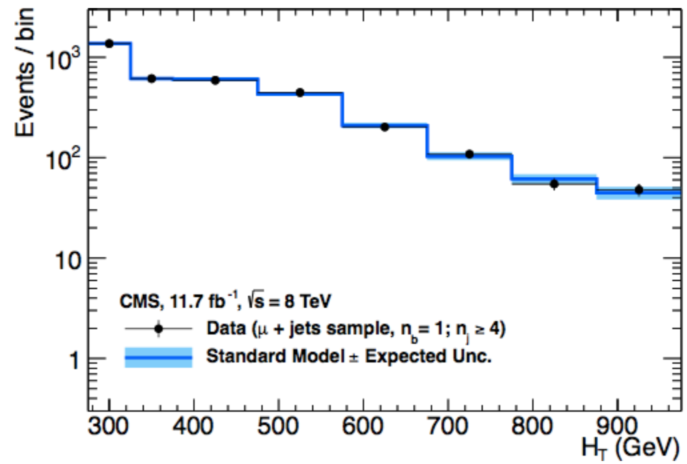
$$R_{\alpha_T}(H_T) = \frac{N(H_T, \alpha_T > 0.55)}{N(H_T, \alpha_T \le 0.55)} = Ae^{kH_T}$$

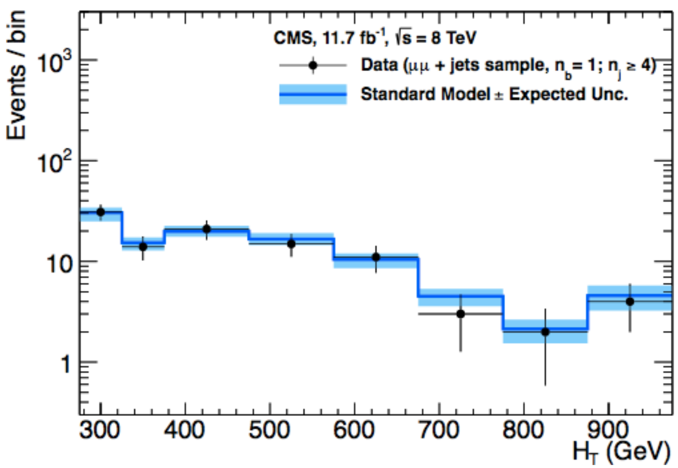
The exponential behavior is validated in a multijet-enriched data sideband.

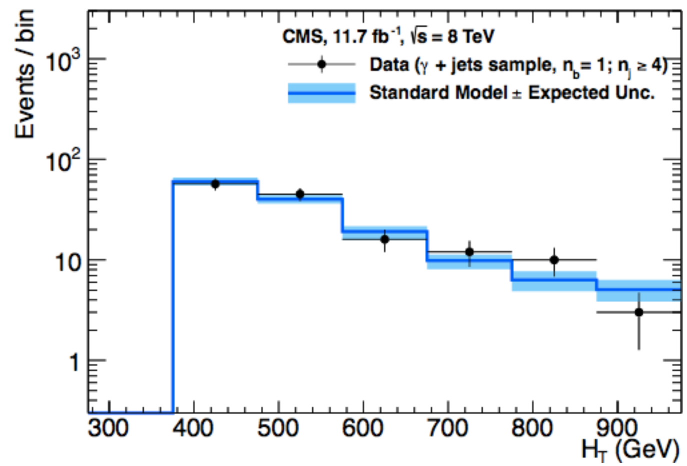
- Likelihood analysis: For a given category satisfying jet and b jet multiplicities, a likelihood model of the observations in multiple data samples is used to obtain a consistent prediction of the SM backgrounds and for the presence of a variety of signal models.

Jets, b-jets, E_T^{miss} with H_T, α_T (8 TeV, 11.7 fb^{-1})
Comparison of observed data and SM yields



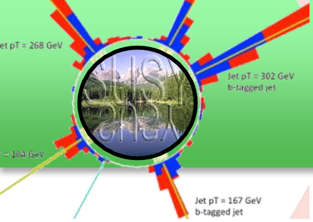




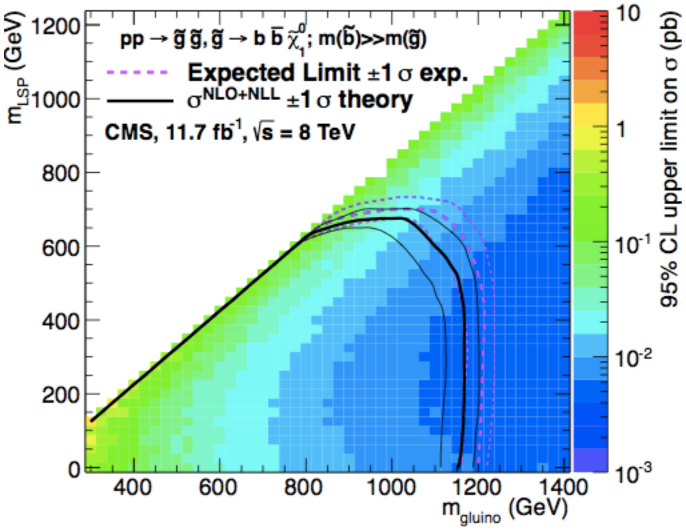


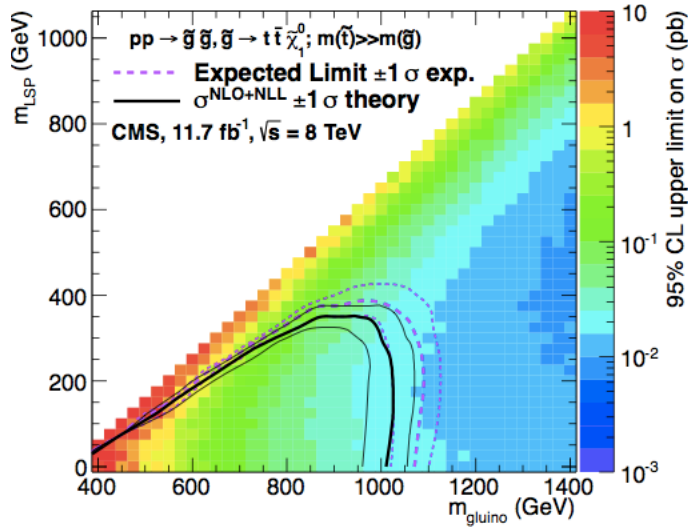
Comparison of observed data and predicted SM yields in the signal and control samples of njets ≥ 4 and nb-jets = 1 category.

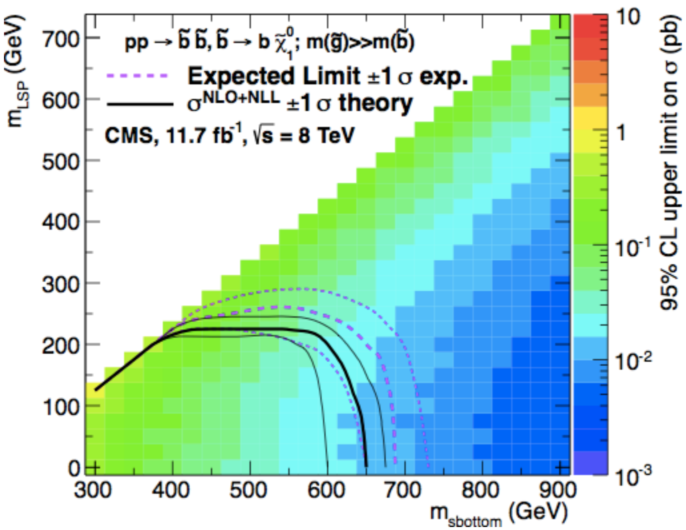
Observation is consistent with the SM (same for all final states).

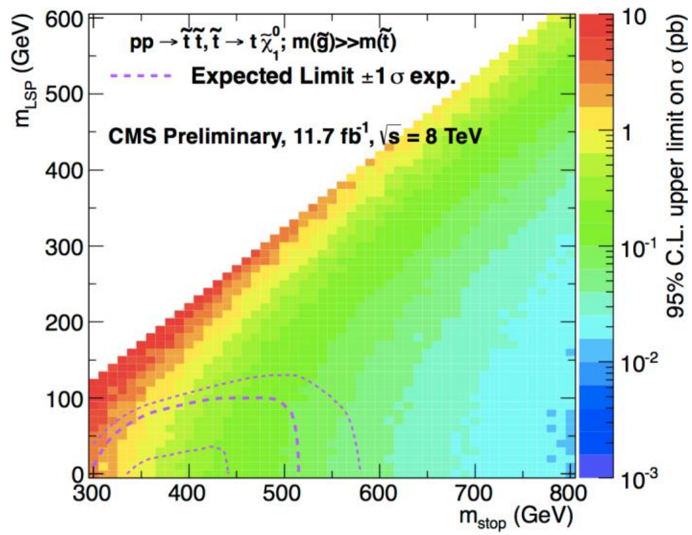


Jets, b-jets, E_T^{miss} with H_T, α_T (8 TeV, 11.7 fb^{-1})
Impact on simplified models



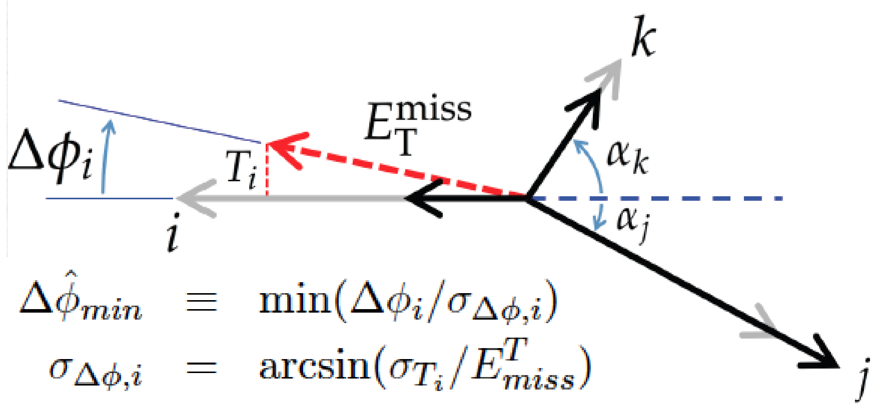






Jets, b-jets, E_T^{miss} with H_T, $\Delta\Phi_{min}$ (8 TeV, 19.4 fb^{-1}) Introduction

Search for 3rd generation-rich SUSY in final states with at least 3 jets, at least 1 b-tagged jet, no isolated leptons and large E_T^{miss}. Search for excess in exclusive bins of H_T, E_T^{miss} and b jet multiplicity.



$$\Delta\hat{\phi}_{min} \equiv \min(\Delta\phi_i/\sigma_{\Delta\phi,i})$$
$$\sigma_{\Delta\phi,i} = \arcsin(\sigma_{T_i}/E^T_{miss})$$
$$\sigma^2_{T_i} \equiv \sum_n (\sigma_{pT,n} \sin\alpha_n)^2$$

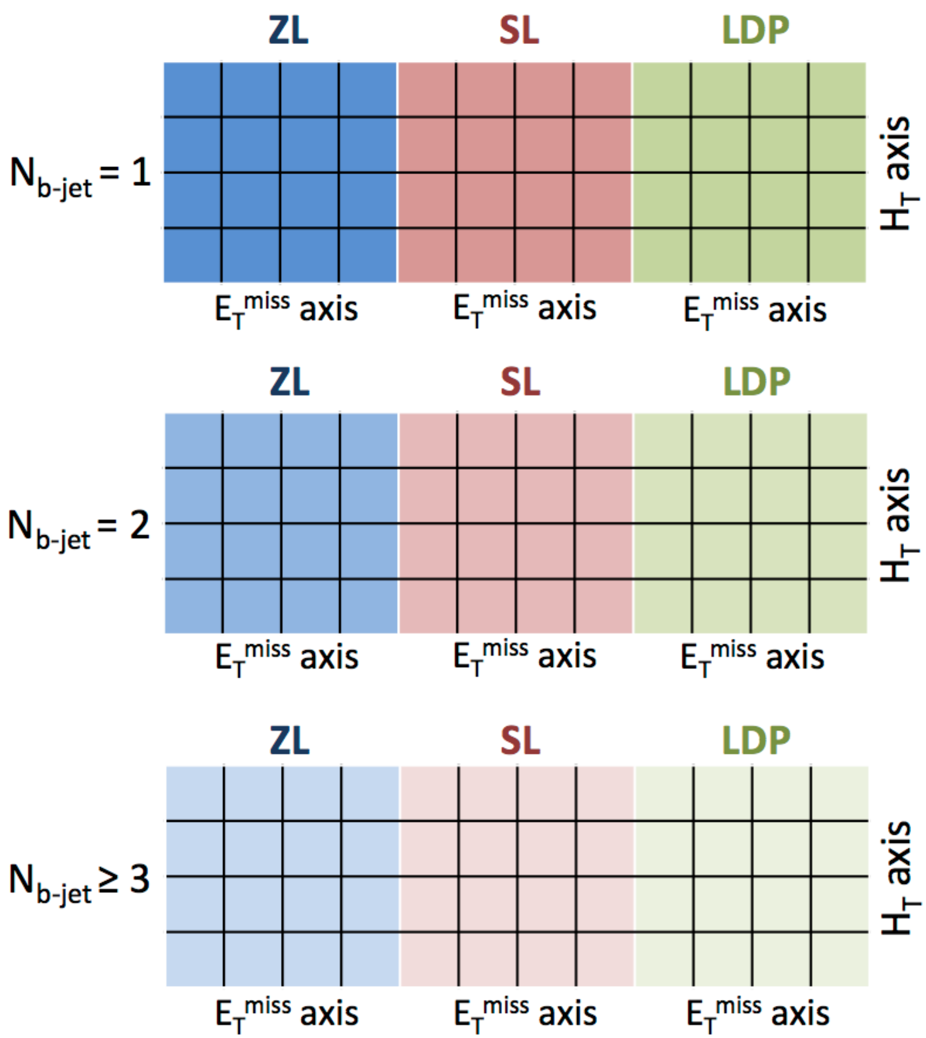
Event selection:

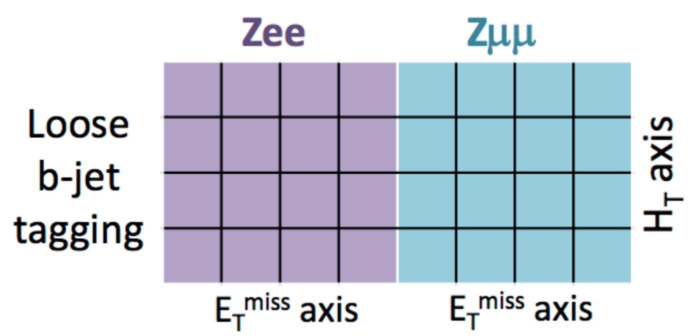
- 1 primary vertex
- ≥3 jets (p_T > 50 GeV, |η| < 2.4)
- jet1, jet2 p_T > 70 GeV
- H_T > 400 GeV
- E_T^{miss} > 125 GeV
- Veto isolated electrons (p_T > 10 GeV, |η| < 2.5) and muons (p_T > 10 GeV, |η| < 2.4)
- No isolated charged track with p_T > 15 GeV, |η| < 2.4
- $\Delta\Phi_{min}$ > 4.0 (for the signal region)
- ≥1 b tagged jets

Jets, b-jets, E_T^{miss} with H_T, $\Delta\Phi_{min}$ (8 TeV, 19.4 fb^{-1})
Signal and control region definitions

Event sample legend

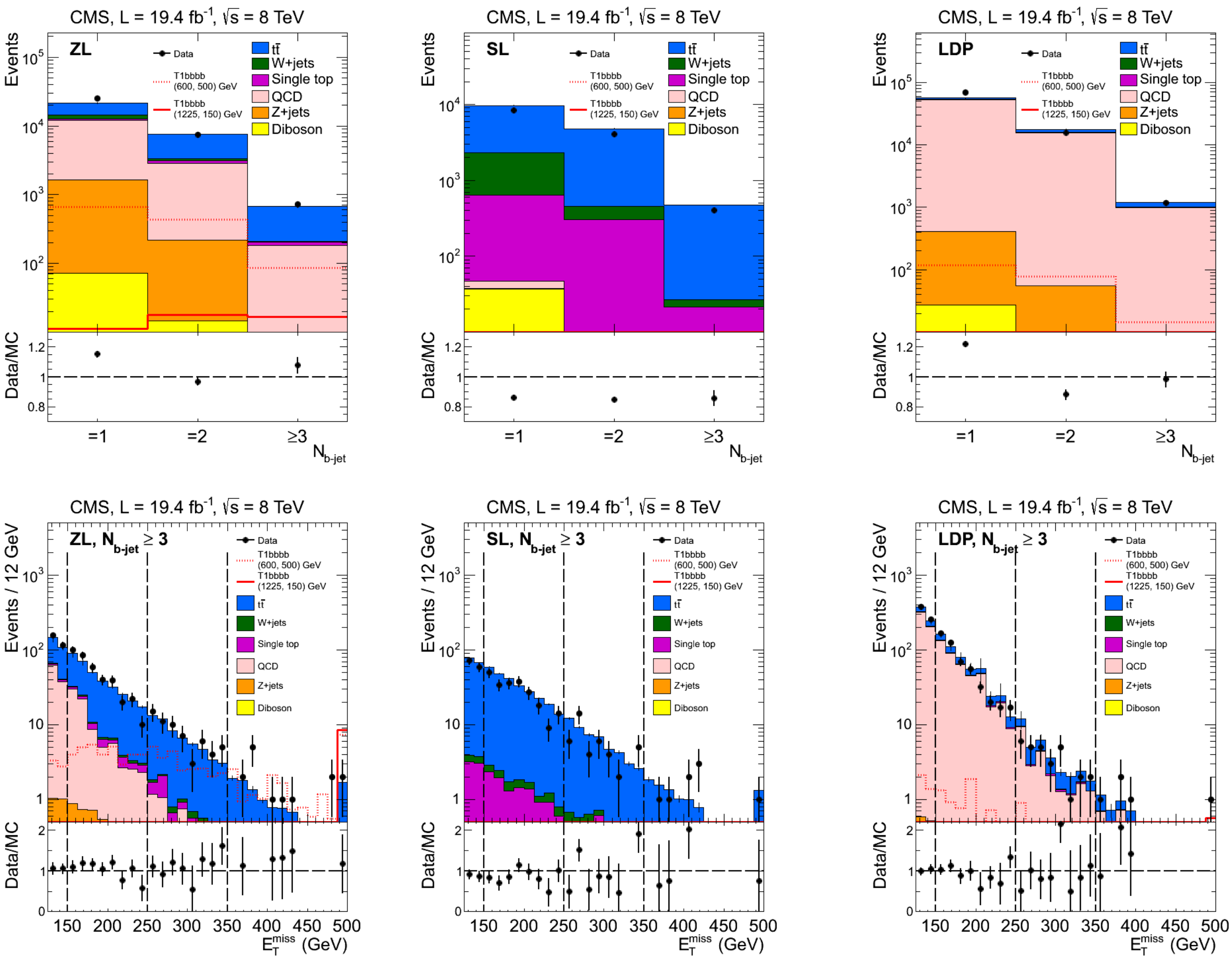
ZL = Zero Lepton; signal sample	**SL** = Single Lepton; top & W+jets control sample	**LDP** = low $\Delta\hat{\phi}_{min}$; QCD control sample	**Zee** = $Z \to e^+e^-$; Z to $\nu\bar{\nu}$ control sample	**Zμμ** = $Z \to \mu^+\mu^-$; Z to $\nu\bar{\nu}$ control sample





Bin	H_T (GeV)	E_T^{miss} (GeV)
1	400 – 500 (HT1)	125 – 150 (MET1)
2	500 – 800 (HT2)	150 – 250 (MET2)
3	800 – 1000 (HT3)	250 – 350 (MET3)
4	> 1000 (HT4)	> 350 (MET4)

Jets, b-jets, E_T^{miss} with H_T, $\Delta\Phi_{min}$ (8 TeV, 19.4 fb^{-1})
Data – MC comparison in signal and control regions



Observed data distributions agree with MC prediction.

MC predictions not used in the analysis (they mainly illustrate the background composition).

Jets, b-jets, E_T^{miss} with H_T, $\Delta\Phi_{min}$ (8 TeV, 19.4 fb^{-1}) BG estimation, likelihood and results

scale factor common to all bins

Expected BG in bin ijk of signal sample

$$\mu^{\mathrm{ttWj}}_{\mathrm{ZL};i,j,k} = S^{\mathrm{ttWj}}_{i,j,k} \cdot R^{\mathrm{ttWj}}_{\mathrm{ZL/SL}} \cdot \mu^{\mathrm{ttWj}}_{\mathrm{SL};i,j,k}$$

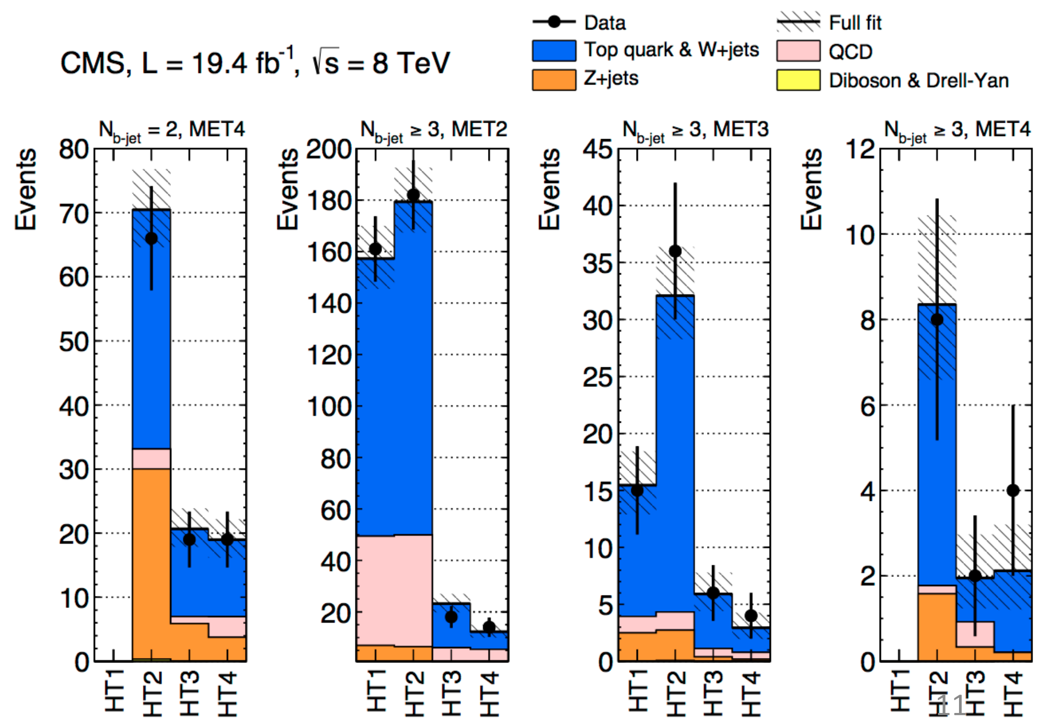
Observed yield in control sample

bin-by-bin MC-based scale factor which accounts for the shape difference between signal and control samples.

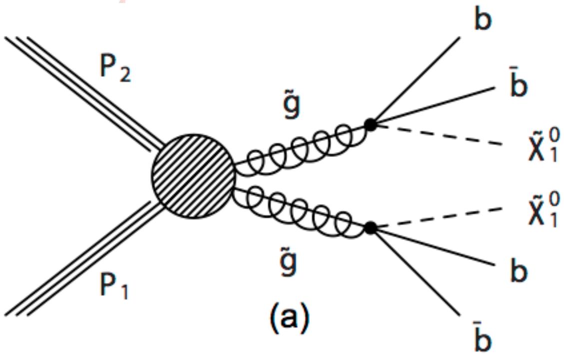
SM contribution is estimated using a likelihood which is a product of Poisson PDFs, one for each bin, and the constraint PDFs for the nuisance parameters.

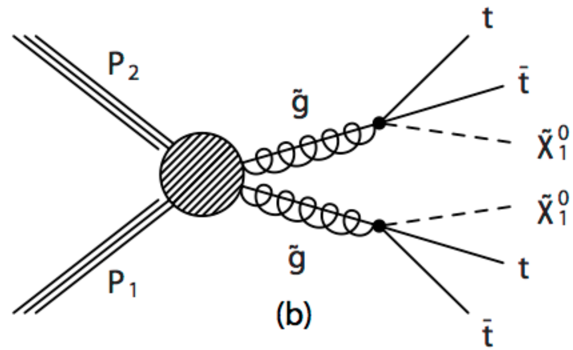
Comparison of data with the SM prediction in the 14 most sensitive bins to new physics.

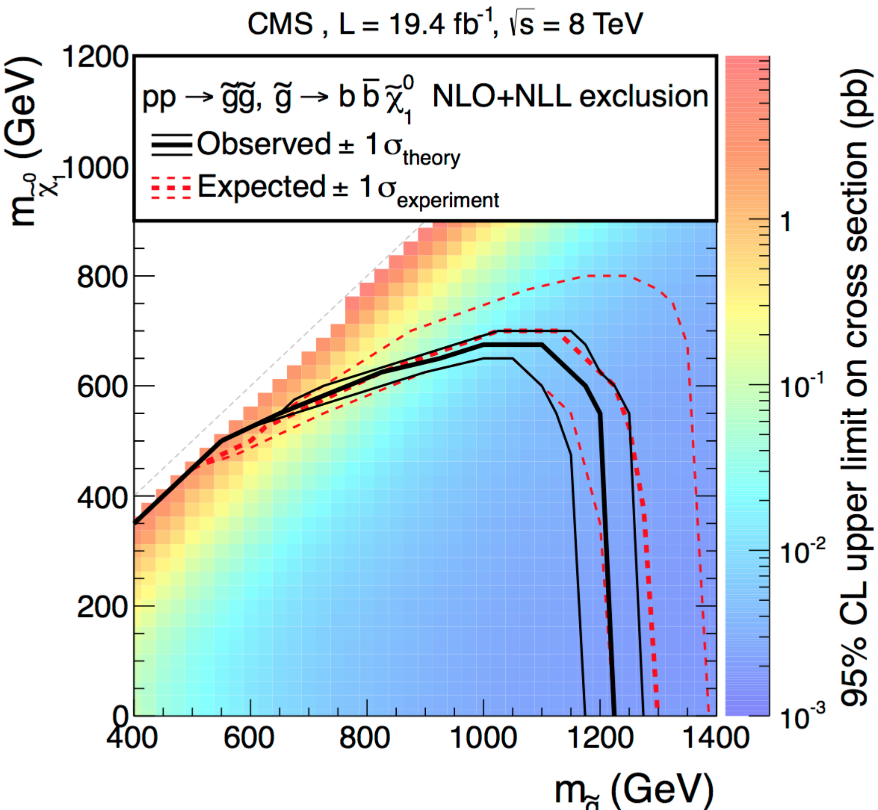
Data consistent with the SM.

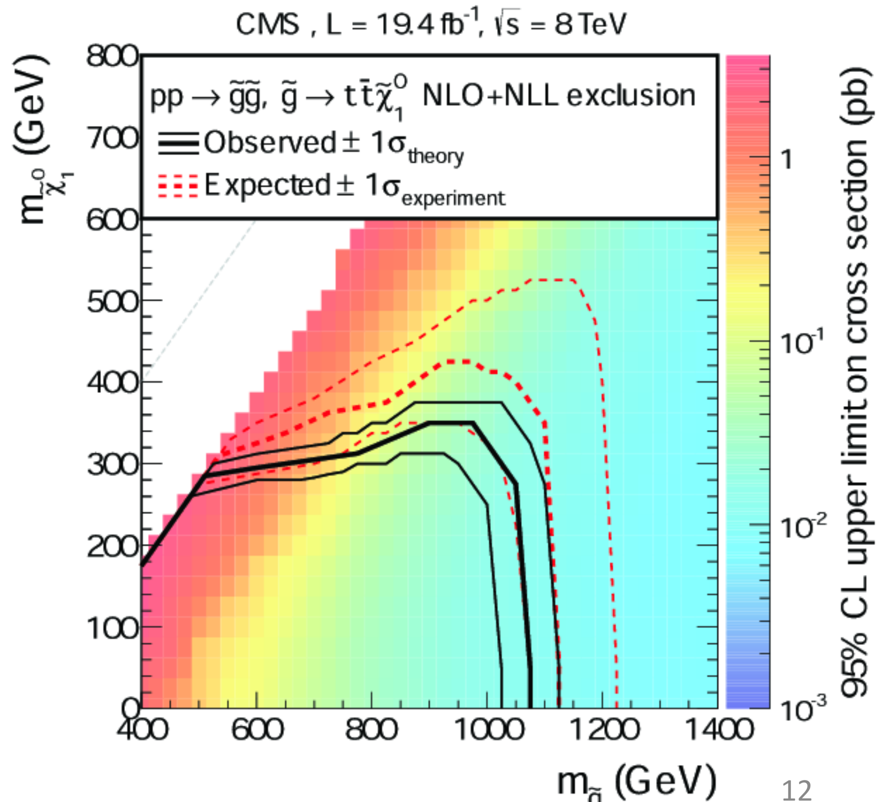


Jets, b-jets, E_T^{miss} with H_T, $\Delta\Phi_{min}$ (8 TeV, 19.4 fb^{-1})
Impact on simplified models





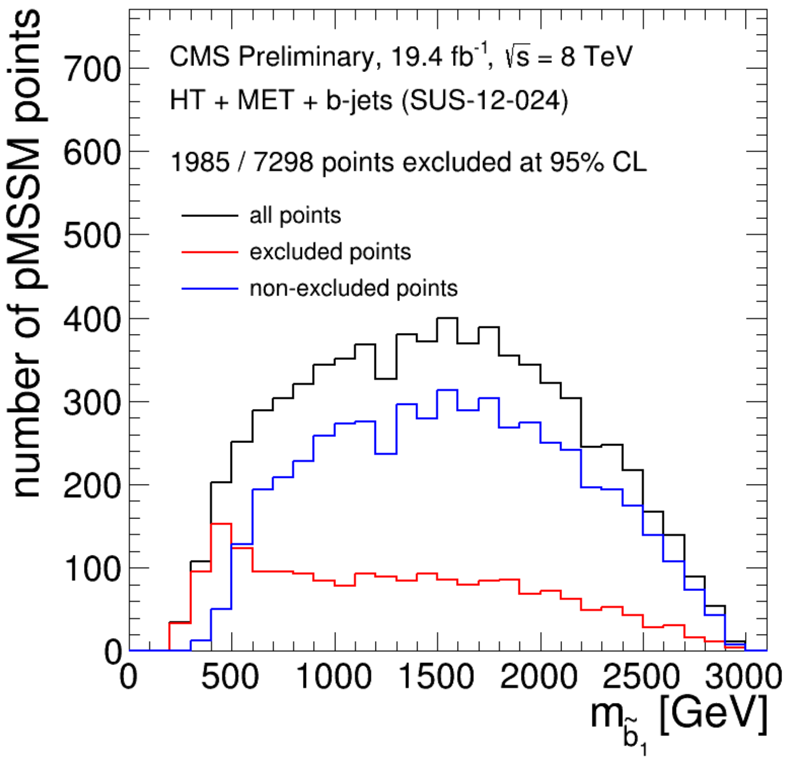


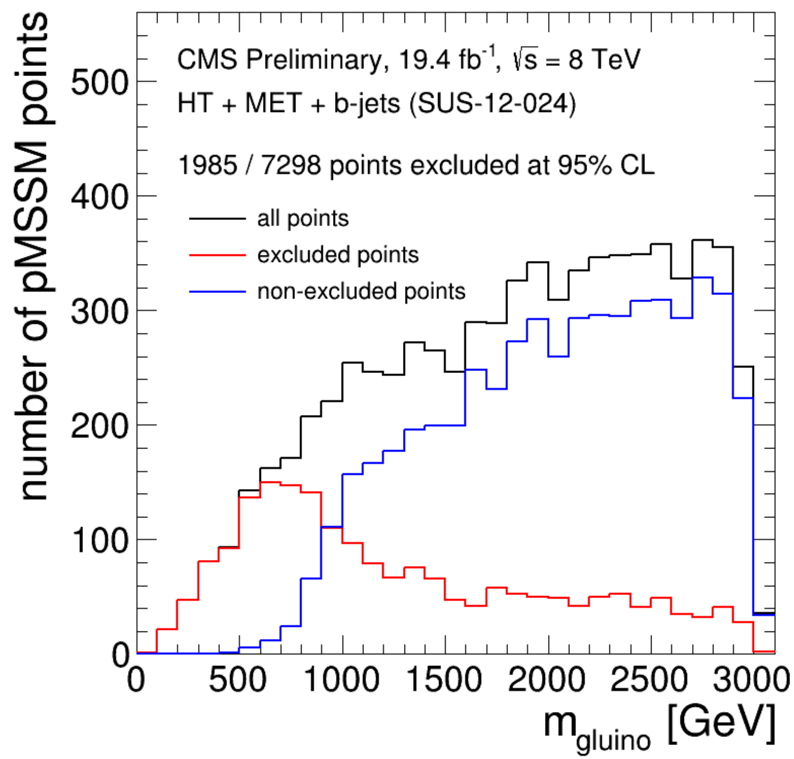


Interlude: CMS and pMSSM

- p(henomenological)MSSM is a 19-dimensional parameterization of MSSM at the SUSY scale.
- pMSSM is defined by
  - 3 gaugino mass parameters
  - 10 sfermion mass parameters
  - 3 trilinear couplings
  - ratio of Higgs VEVs $\tan\beta$, Higgsino mass parameter μ and pseudoscalar Higgs mass m_A
  - plus a set of minimal assumptions.
- It is a full model with no assumptions on the nature of SUSY breaking mechanism and no correlations between the sparticle masses. It allows to make generic statements on sparticle masses.
- pMSSM in CMS: Sampled ~7300 pMSSM points from a likelihood of preCMS measurements (EW observables, b physics, ...) and analyzed the impact of CMS analyses on the sparticle mass distributions.

Jets, b-jets, E_T^{miss} with H_T, $\Delta\Phi_{min}$ (8 TeV, 19.4 fb^{-1})
Impact on pMSSM mass distributions





- Light gluinos (particularly decaying to 3rd generation) are disfavored.
- Light sbottoms are disfavored. This search has a visible impact up to 700 GeV
- There is no significant impact on the light stop mass distribution (not shown here).

Conclusions

- CMS has been looking for natural SUSY with inclusive searches (shown here) and direct stop searches.
- Final states with multiple jets, high missing transverse energy and b tagged jets have been studied using different kinematic variables such as α_T, H_T and $\Delta\Phi_{min}$
- With up to 19.5 fb^{-1} of 8 TeV pp data, no excess over the SM has been observed.
- Impact of this absence has been studied on simplified models and phenomenological MSSM.
    - gluinos probed up to ~1.2 TeV
    - stops probed up to ~500 GeV
    - sbottoms probes up to ~650 GeV

No SUSY yet?