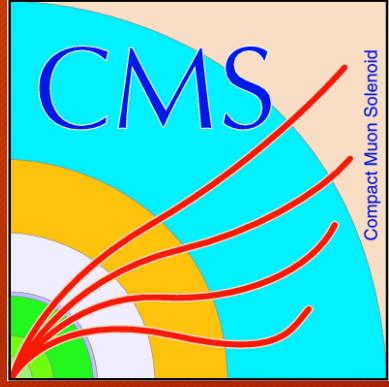
UIC



CMS-SUS-16-050

Search for supersymmetry with a top tagger

Hui Wang

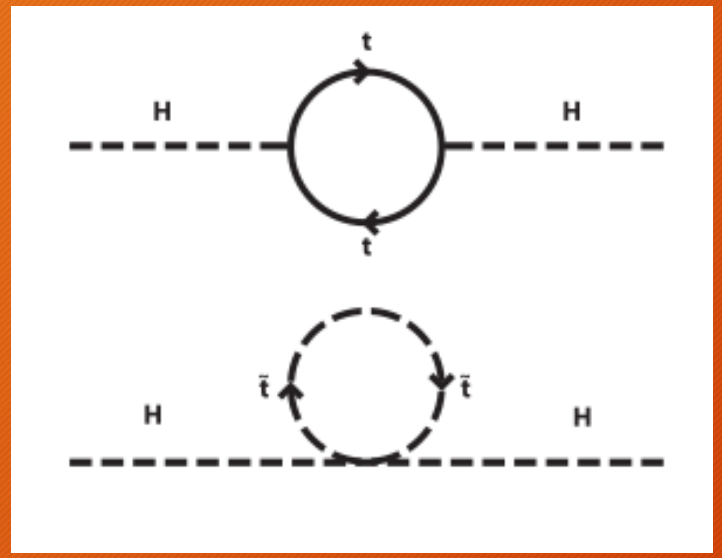
University of Illinois at Chicago

USLUA meeting

November 3, 2017

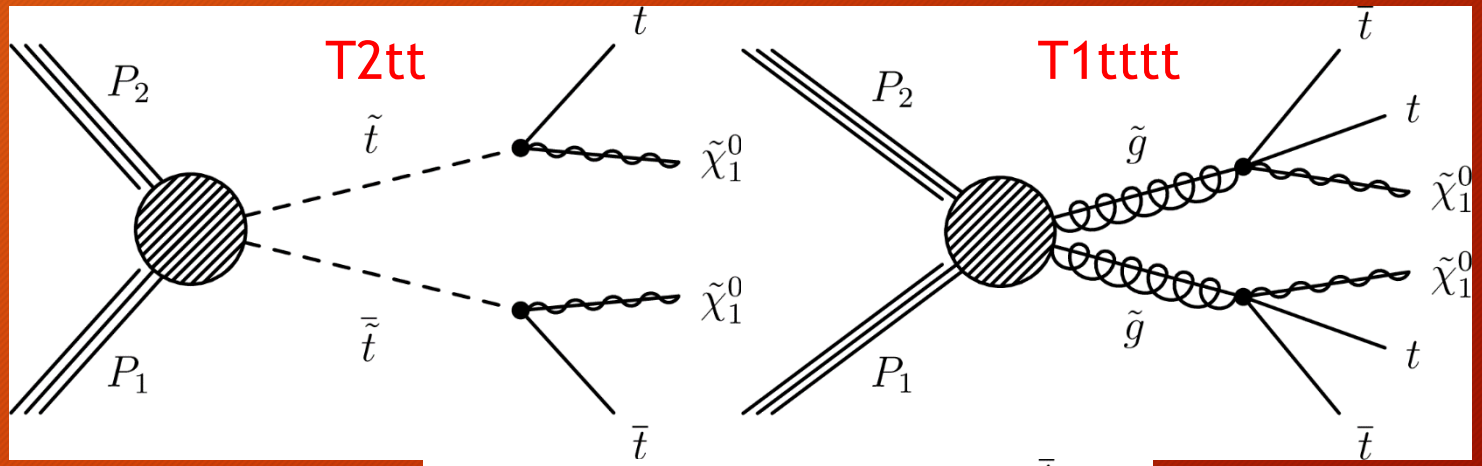
Introduction

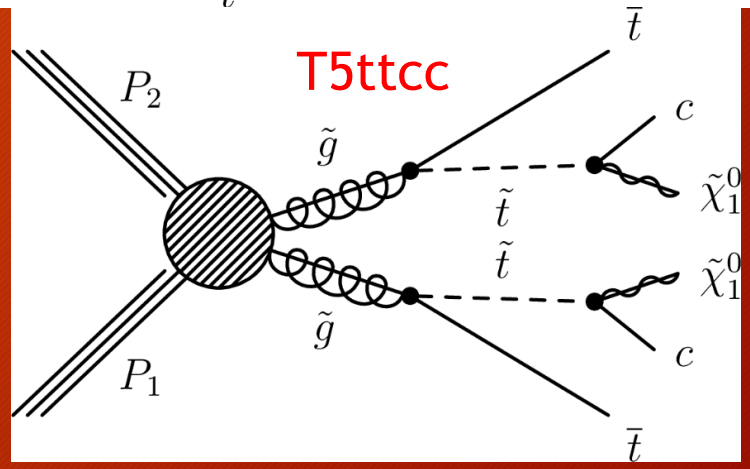
Why sTop?



- Top contributes most to the quantum correction of Higgs mass
- SUSY broken
- Natural models of SUSY:
  sTop mass less than a few TeV

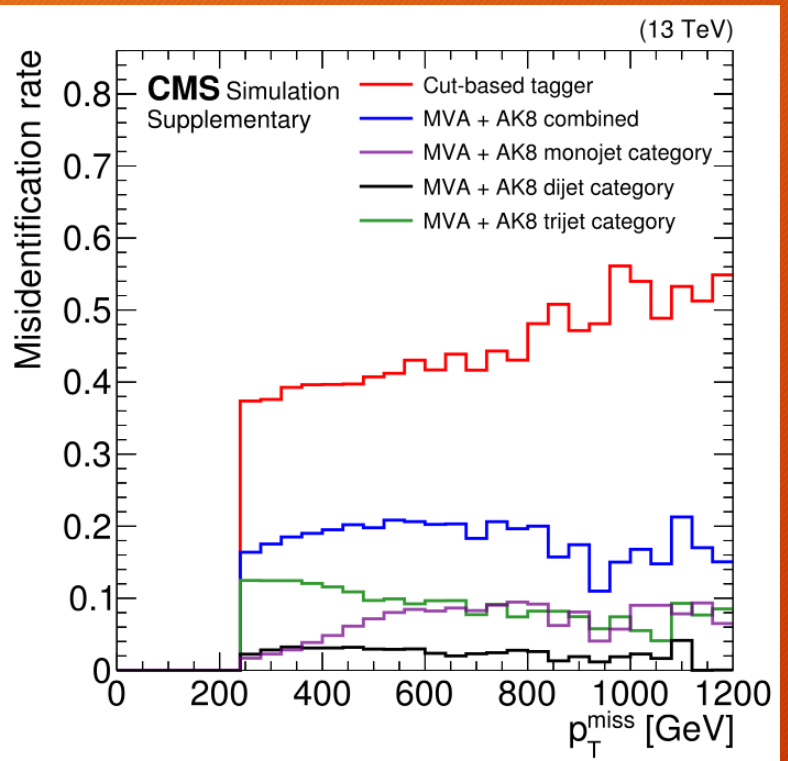
Simplified SUSY models

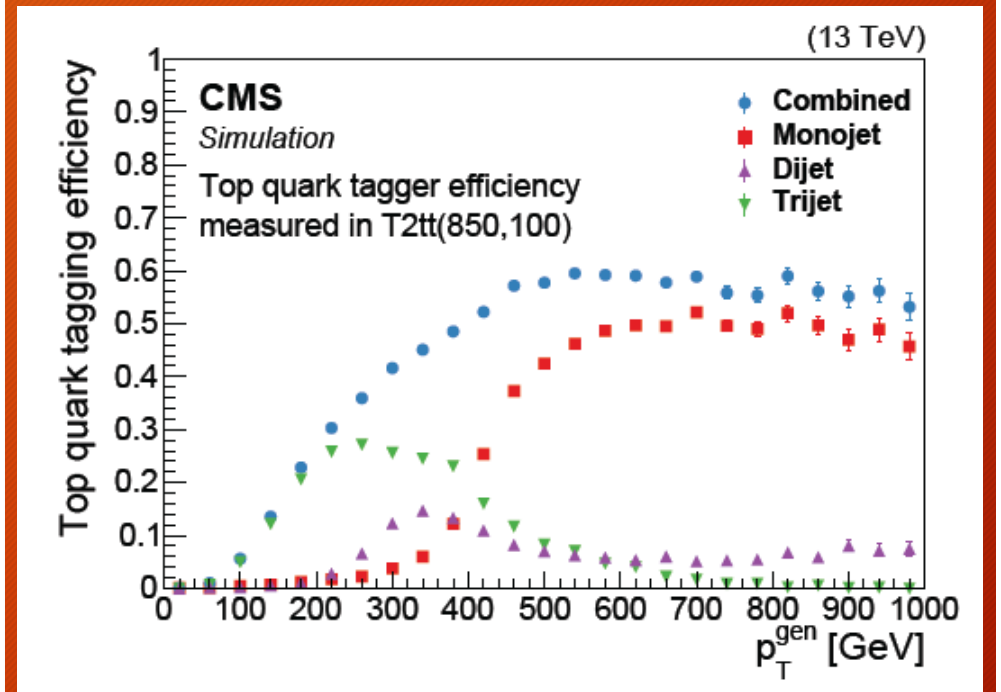


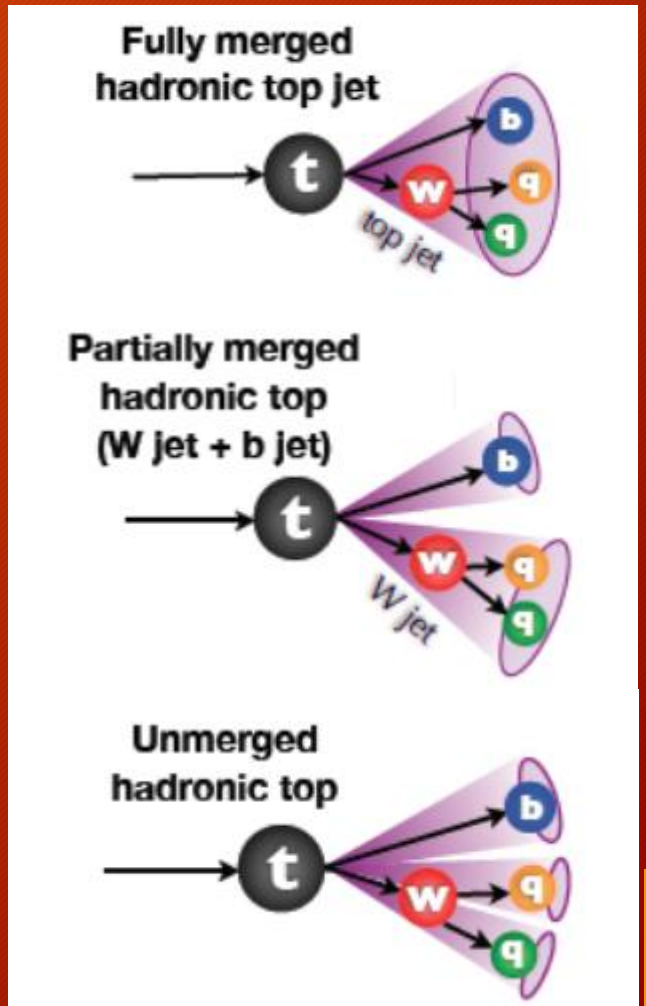


Top tagger

Many thanks to Ken Call for his nice introduction of our powerful top tagger!







Baseline and Search Bin

- Jets and $pTmiss$:
  - $Njets$ (pT > 50) ≥ 2
  - $Njets$ (pT > 30) ≥ 4
  - $pTmiss$> 250 GeV
  - HT> 300 GeV
  - $\Delta\phi$ (j1,2,3, $pTmiss$) >0.5, 0.3, 0.3
  - Nb ≥ 1
- Lepton veto :
  - Ne, Nμ and Nτ = 0
- Top reconstruction:
  - Nt ≥ 1 with top tagger
  - $MT2$ > 200 GeV

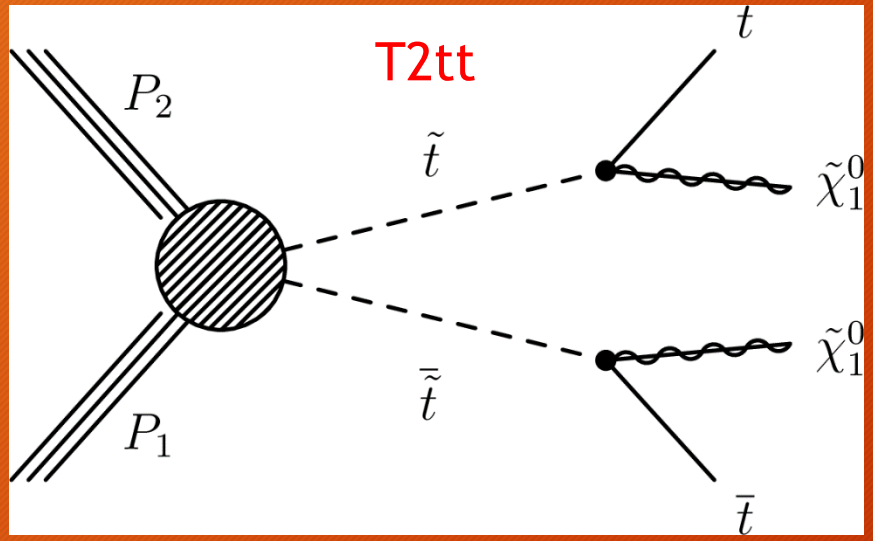
Binning variables

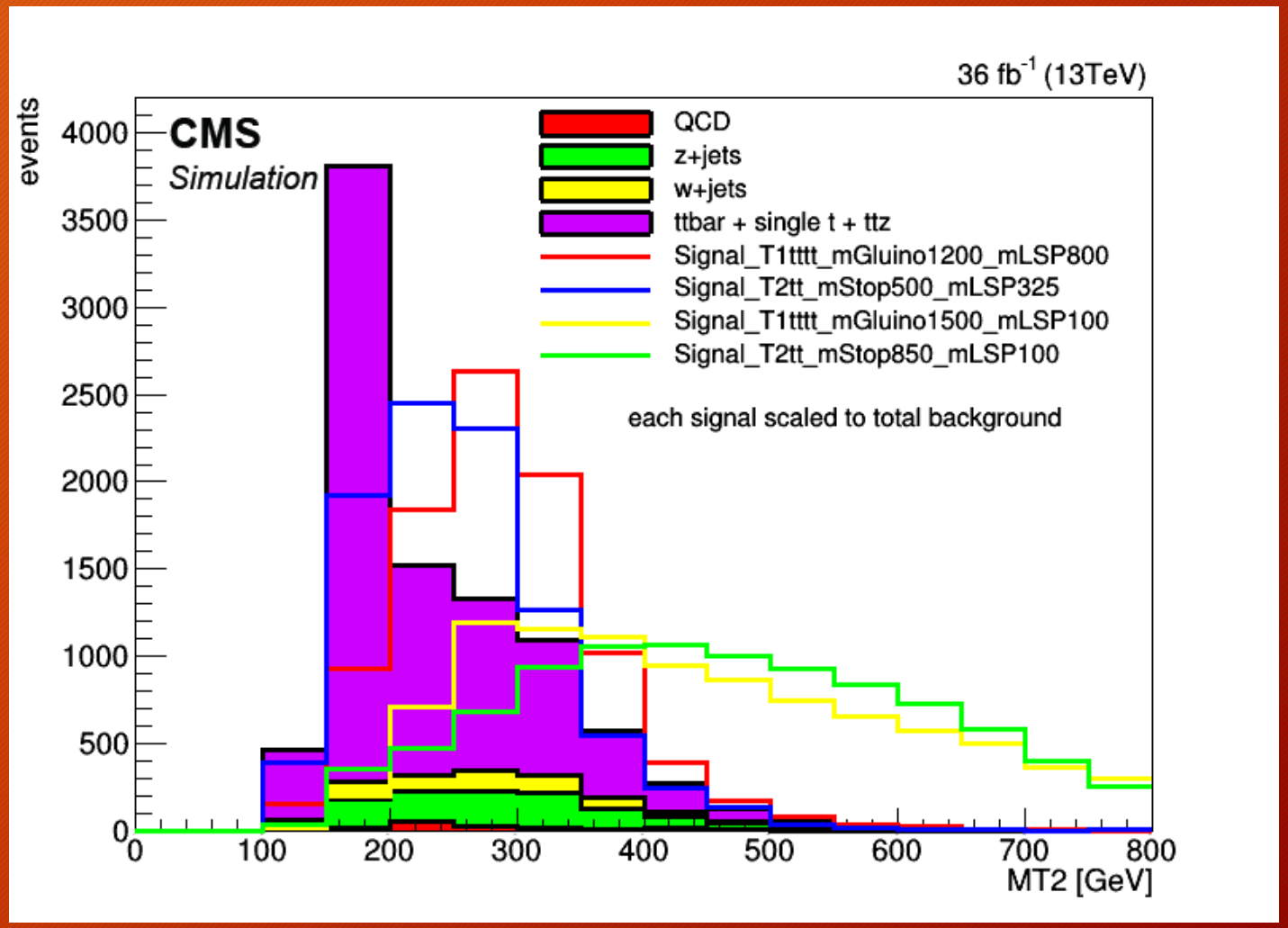
N_t \ N_b	1	2	≥3
1	p_T^{miss}, M_{T2}	p_T^{miss}, M_{T2}	p_T^{miss}, H_T
2	p_T^{miss}, M_{T2}	p_T^{miss}, M_{T2}	p_T^{miss}, H_T
≥3	p_T^{miss}, H_T	p_T^{miss}, H_T	p_T^{miss}, H_T

MT2

MT2: an extension of MT (transverse mass)

A special algorithm to separate $pTmiss$ into two parts, associated with two Tops





Background estimation

- Dominant Backgrounds
  - $t\bar{t}$/single top/W+$jets$ (~75%)

Estimated by data driven approach using translation factors

  - $Z(\nu\nu)$+$jets$ (~17%)

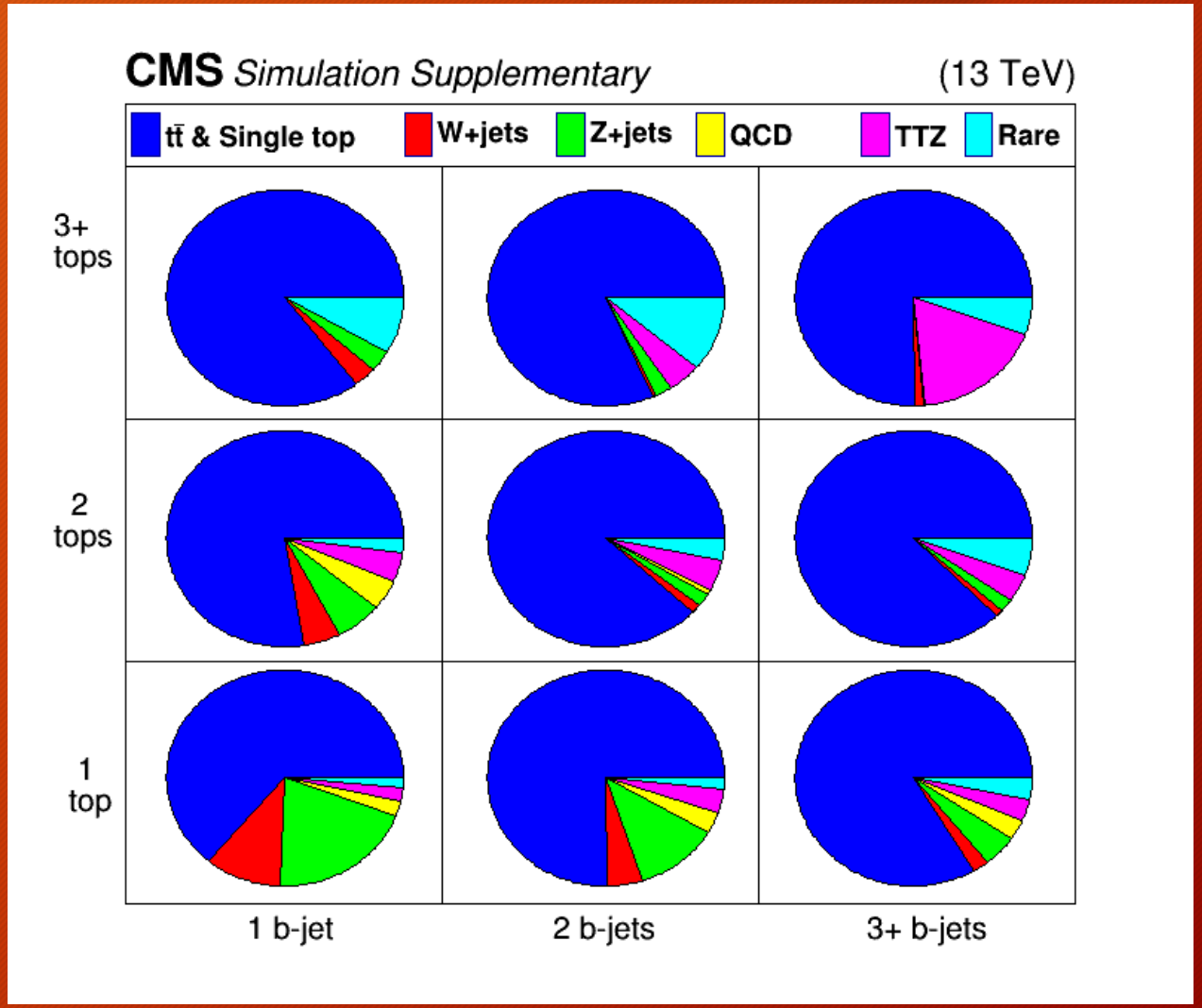
Estimated by data corrected MC

  - QCD (~3%)

Estimated in data sideband with data-normalized translation factors derived from MC

- Sub-dominant backgrounds
  - $t\bar{t}Z$ (~2%)
  - Rare (~3%)

Estimated from MC

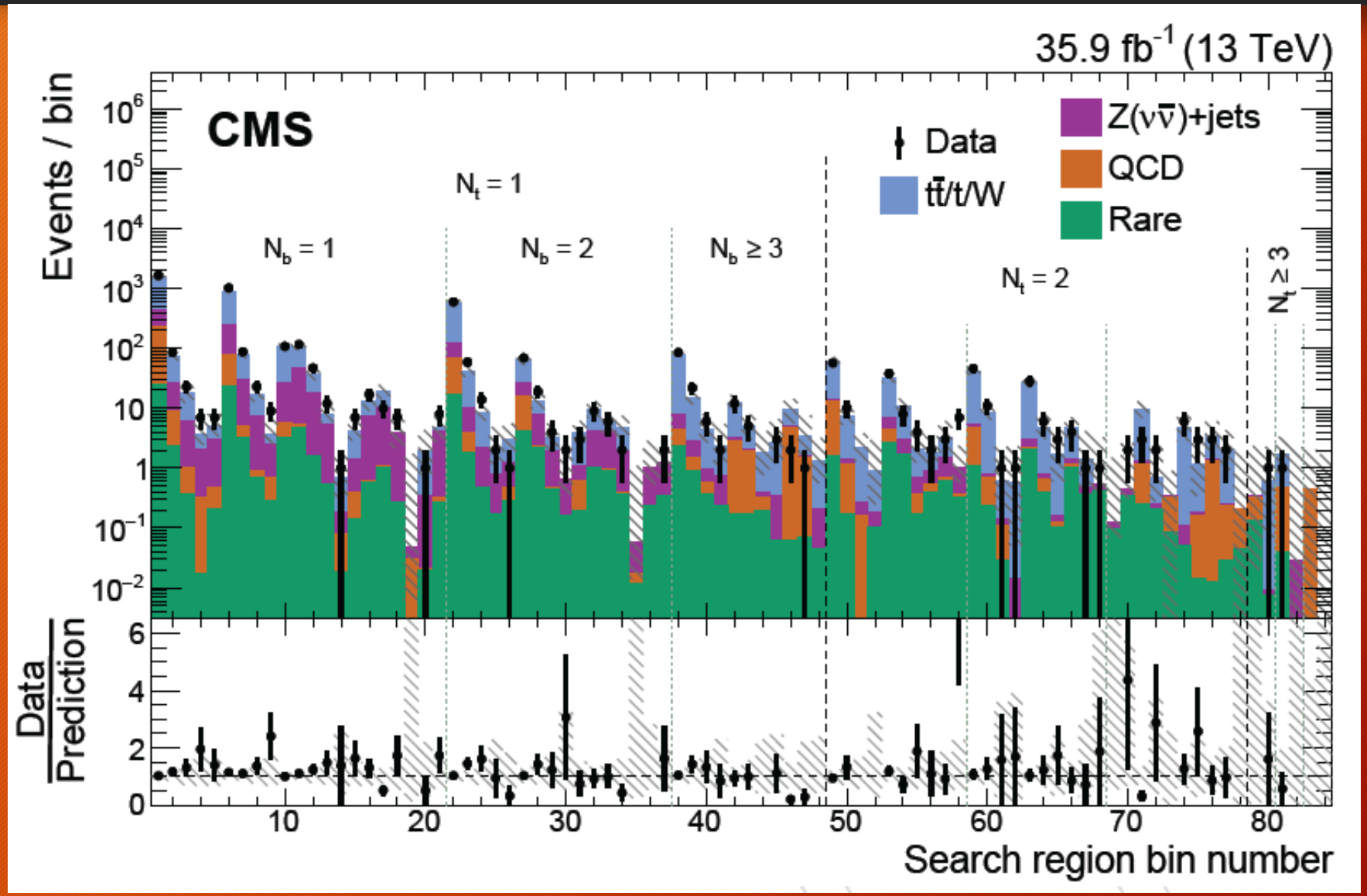


Translation Factor method

Lost lepton (LL) events in $t\bar{t}$/single top/W+$jets$

	Control region (CR) Baseline cut without lepton veto		Signal region (SR) Baseline cut
MC	Ncr (MC) = number of events in MC CR		Nsr = number of events with gen level LL in MC SR
		TF = $\frac{Nsr}{Ncr}$	
data	Ncr (data) = number of events in data CR		LL background prediction = Ncr(data) * TF

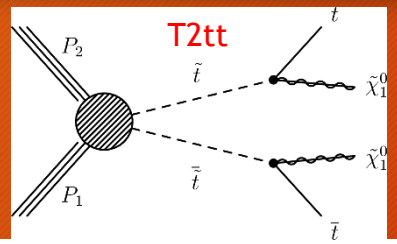
Results


35.9 fb^{-1} (13 TeV)
CMS
Data
tt̄/t/W
Z(νν̄)+jets
QCD
Rare
Events / bin
$N_t = 1$
$N_t = 2$
$N_t \geq 3$
$N_b = 1$
$N_b = 2$
$N_b \geq 3$
Data / Prediction
Search region bin number

Limits - T2tt

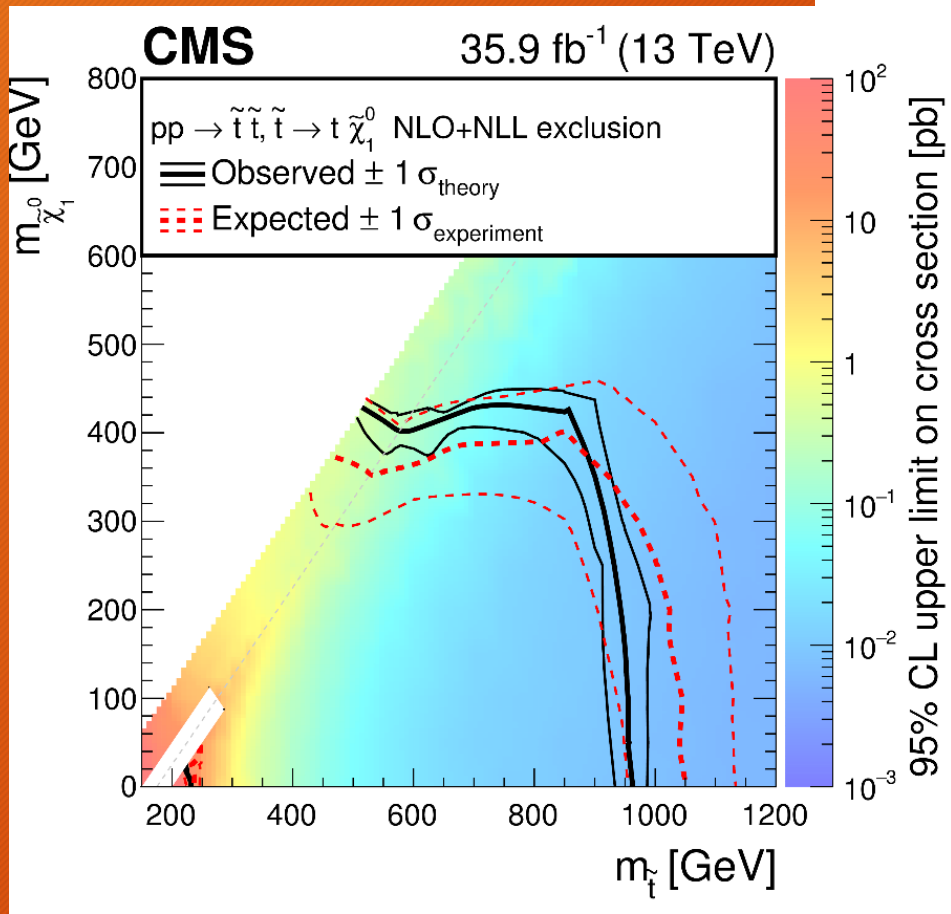
Limits without top tagger

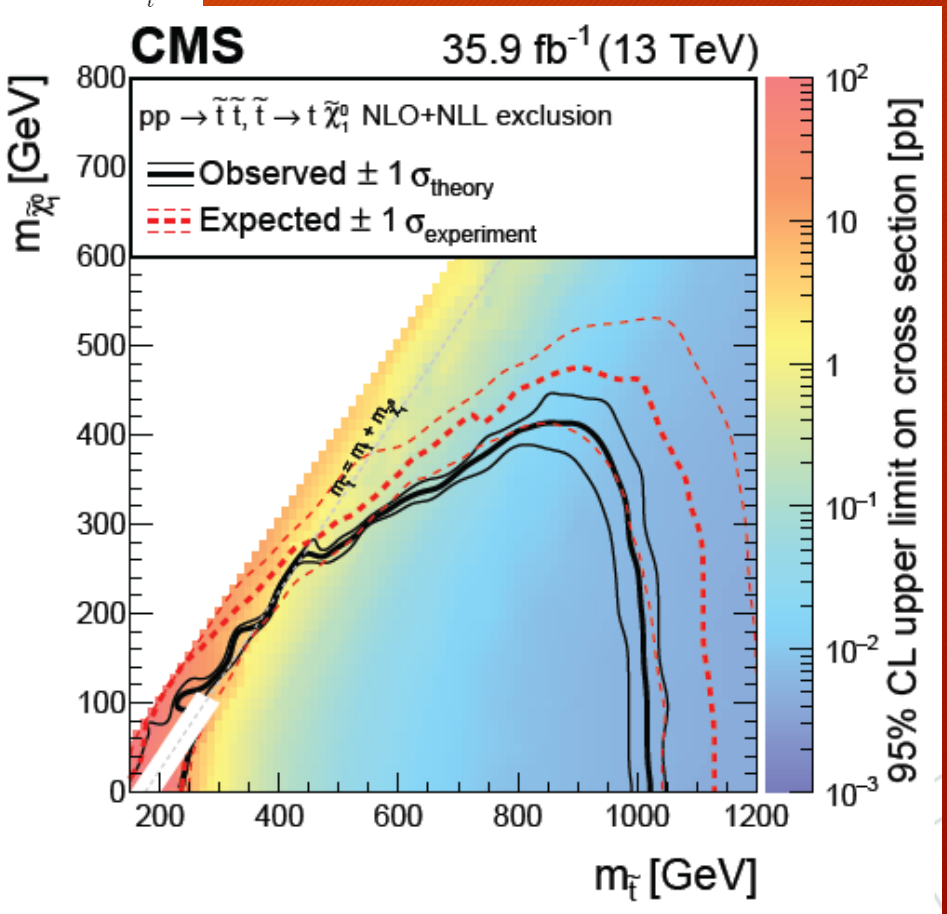
http://cms-results.web.cern.ch/cms-results/public-results/publications/SUS-16-033/index.html



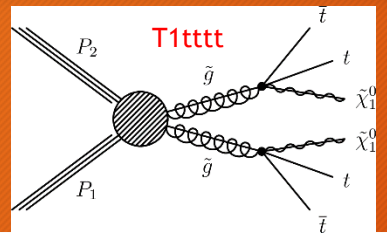
Limits with top tagger

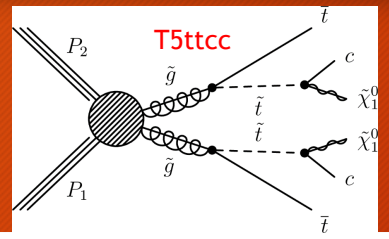
http://cms-results.web.cern.ch/cms-results/public-results/preliminary-results/SUS-16-050/index.html

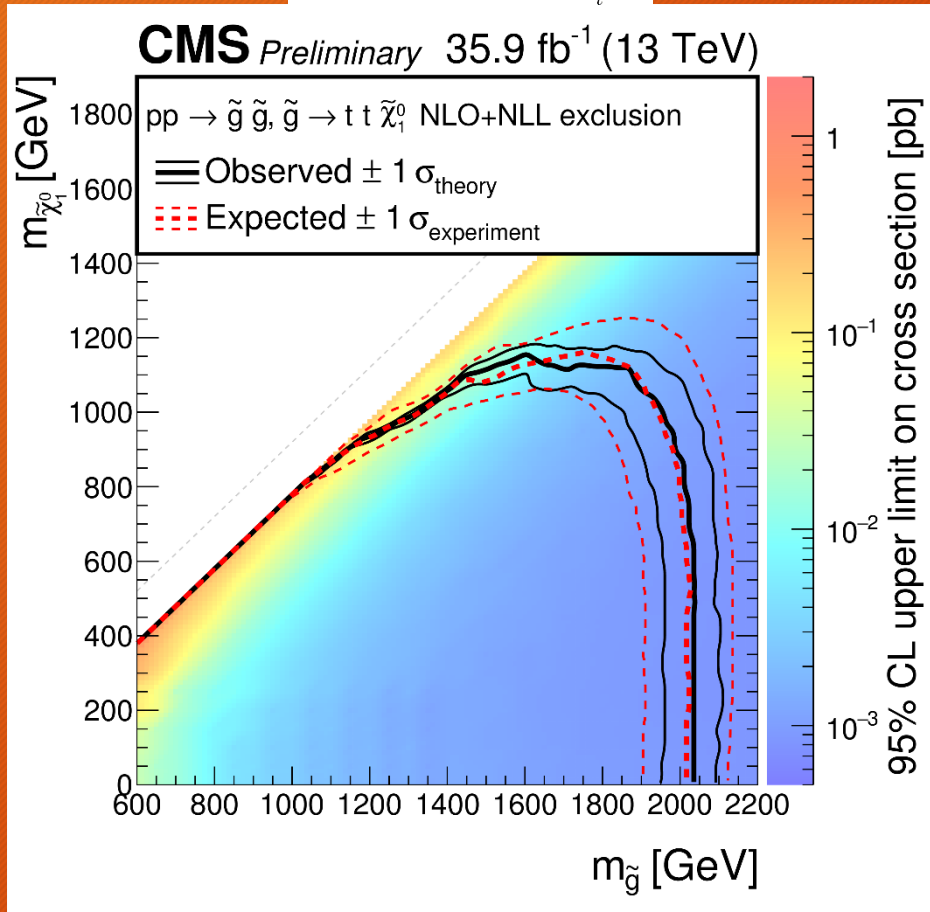


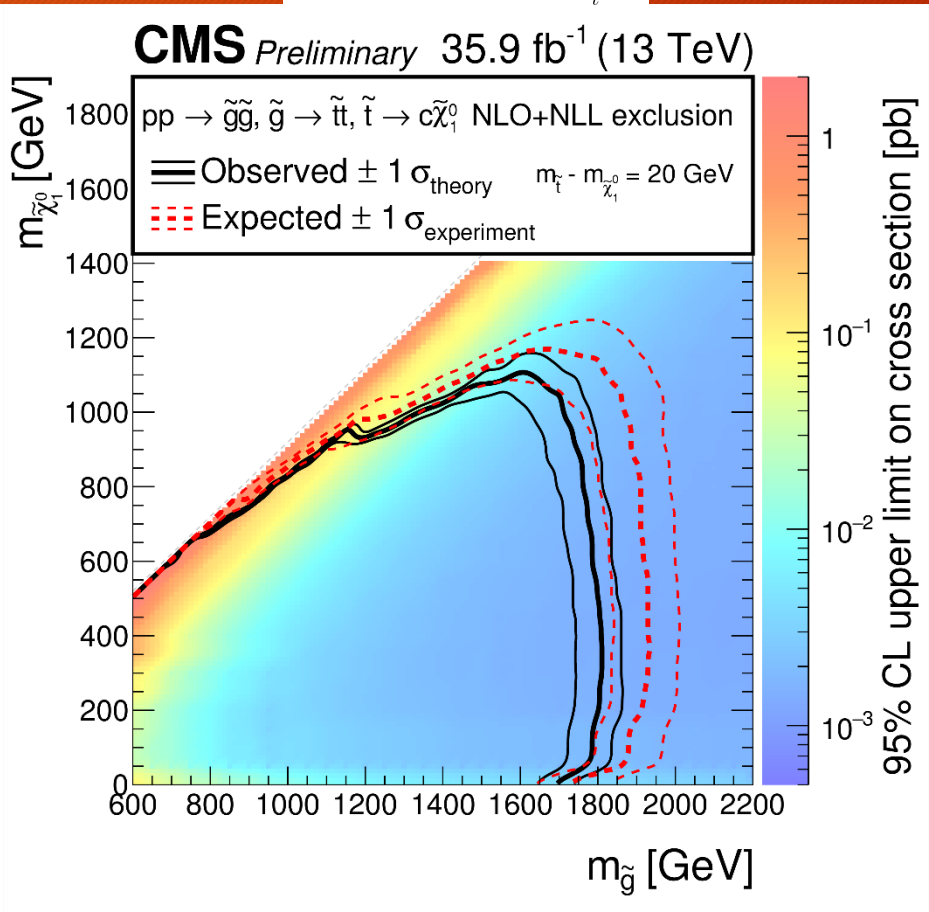


Limits - T1tttt and T5ttcc

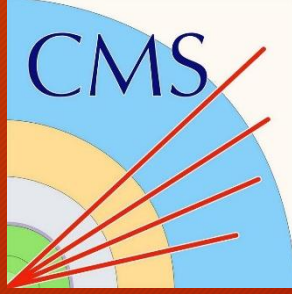








Conclusion and Outlook



- A powerful top tagger is designed and applied in our analysis
- We have elaborately worked out the background
- No statistically significant excess of Standard Model is observed
- The previous limits of the masses of SUSY particles are extended

- Future of our analysis:
  Even more powerful top tagger with neural network
  Search region expansion, especially at compressed region

Thank you for your attention!

Backup slides

Documentation and team member

- Documentation:

http://cms-results.web.cern.ch/cms-results/public-results/publications/SUS-16-050/index.html

- Team member:

Baylor University: K. Hatakeyama, J. Dittmann, H. Liu, J. Pastika, K. Call

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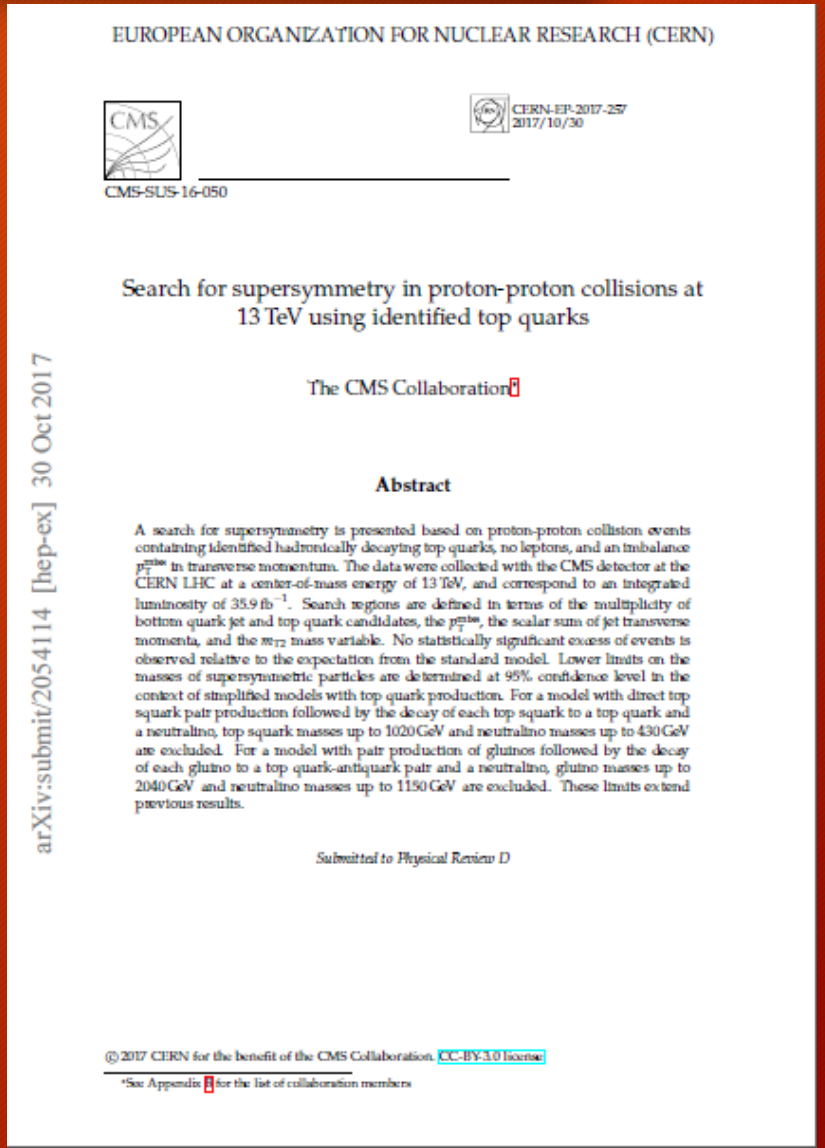
University of Illinois at Chicago: R. Cavanaugh, Z. Wu, H. Wang

University of Puerto Rico Mayaguez: S. Malik, S. Norberg, A. Abreu



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

CERN-EP-2017-257
2017/10/30

CMS-SUS-16-050

Search for supersymmetry in proton-proton collisions at 13 TeV using identified top quarks

The CMS Collaboration*

arXiv:submit/2054114 [hep-ex] 30 Oct 2017

Abstract

A search for supersymmetry is presented based on proton-proton collision events containing identified hadronically decaying top quarks, no leptons, and an imbalance p_T^{miss} in transverse momentum. The data were collected with the CMS detector at the CERN LHC at a center-of-mass energy of 13 TeV, and correspond to an integrated luminosity of 35.9 fb^{-1}. Search regions are defined in terms of the multiplicity of bottom quark jet and top quark candidates, the p_T^{miss}, the scalar sum of jet transverse momenta, and the m_{T2} mass variable. No statistically significant excess of events is observed relative to the expectation from the standard model. Lower limits on the masses of supersymmetric particles are determined at 95% confidence level in the context of simplified models with top quark production. For a model with direct top squark pair production followed by the decay of each top squark to a top quark and a neutralino, top squark masses up to 1020 GeV and neutralino masses up to 430 GeV are excluded. For a model with pair production of gluinos followed by the decay of each gluino to a top quark-antiquark pair and a neutralino, gluino masses up to 2040 GeV and neutralino masses up to 1150 GeV are excluded. These limits extend previous results.

Submitted to Physical Review D

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*See Appendix B for the list of collaboration members

Baseline detail

- Top reconstruction:
  - Nt≥1with top tagger
  - $MT2$>200GeV
- Jets and $pTmiss$:
  - AK4PF jets with CHS: $Njets(pT>50)\geq 2$ $Njets(pT>30)\geq 4$
  - $pTmiss$> 250 GeV
  - HT> 300 GeV
  - $\Delta\phi(j1,2,3,\ pTmiss)$ >0.5,0.3,0.3
  - Nb≥1(CSVM)
- Lepton/track veto:
  - μ veto: pT>10GeV, medium ID && miniISO
  - e veto: pT>10GeV, veto ID && miniISO
  - IsoTrack: e/μtrack (relIso< 0.2 && pT>5GeV) or πtrack (relIso< 0.1 && pT>10GeV), MtW<100GeV
- Noise cleaning:
  - HBHENoiseFilter, HBHENoiseIsoFilter, EcalDeadCellTriggerPrimitiveFilter, GoodVertices, eeBadScFilter, CSCTightHalo2016Filter, badPFMuonFilter, badChargedHadronFilter, LooseJetID+ PFMET/CaloMET<5

MT2 detail

- Also known as The Stransverse Mass
- Author website:
- http://www.hep.phy.cam.ac.uk/~lester/mt2/

$$\tilde{l} \to l\tilde{\chi} \tag{6}$$

for arbitrary momenta we can write,

$$m_{\tilde{l}}^2 = m_l^2 + m_{\tilde{\chi}}^2 + 2(E_{Tl}E_{T\tilde{\chi}}\cosh(\Delta\eta) - \mathbf{p}_{Tl}\cdot\mathbf{p}_{T\tilde{\chi}}) \tag{7}$$

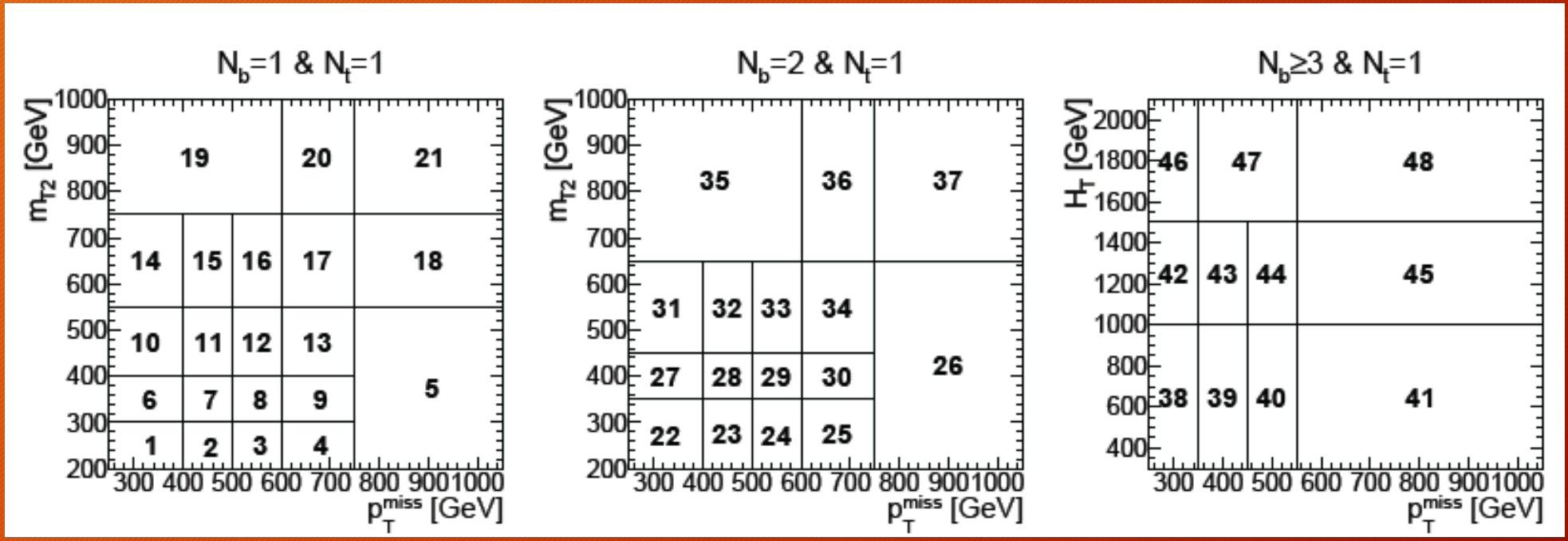
where $E_T = \sqrt{\mathbf{p}_T^2 + m^2}$ and $\Delta\eta$ is the difference in rapidity, $\eta = \frac{1}{2}\ln[(E+p_z)/(E-p_z)]$, between between the l and $\tilde{\chi}$.

Now as $\cosh\eta \geq 1$ we have,

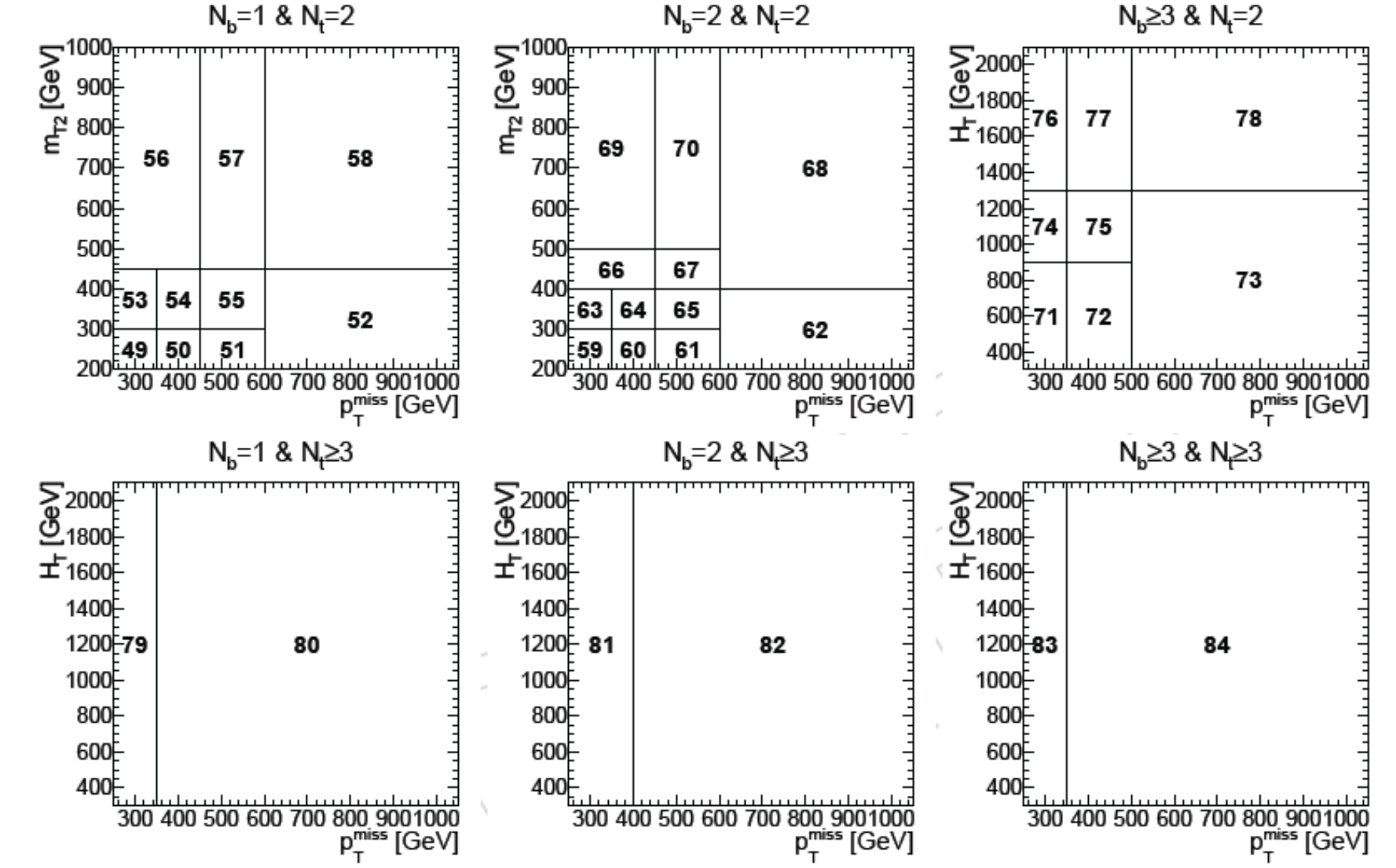
$$m_{\tilde{l}}^2 \geq m_T^2(\mathbf{p}_{Tl}, \mathbf{p}_{T\tilde{\chi}}) \equiv m_l^2 + m_{\tilde{\chi}}^2 + 2(E_{Tl}E_{T\tilde{\chi}} - \mathbf{p}_{Tl}\cdot\mathbf{p}_{T\tilde{\chi}}). \tag{8}$$

Search bins detail

- 84 search bins in Nb, Nt, $pTmiss$, $MT2/HT$
- Nb, Nt=1,2: Targeting T2tt, each block is binned in $pTmiss$, $MT2$
- Nb or $Nt\geq3$: Targeting T1tttt, each block is binned in $pTmiss$, HT



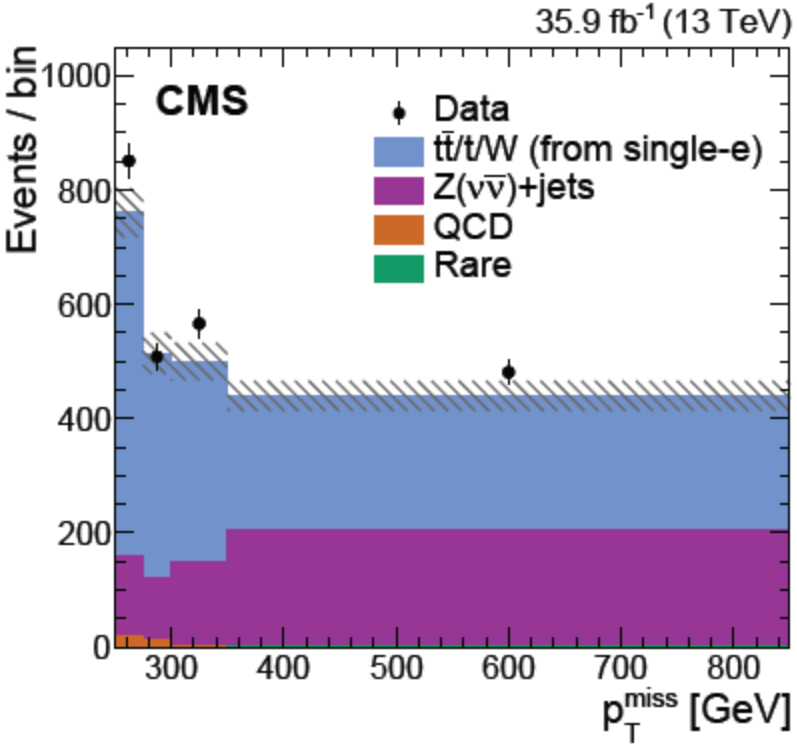
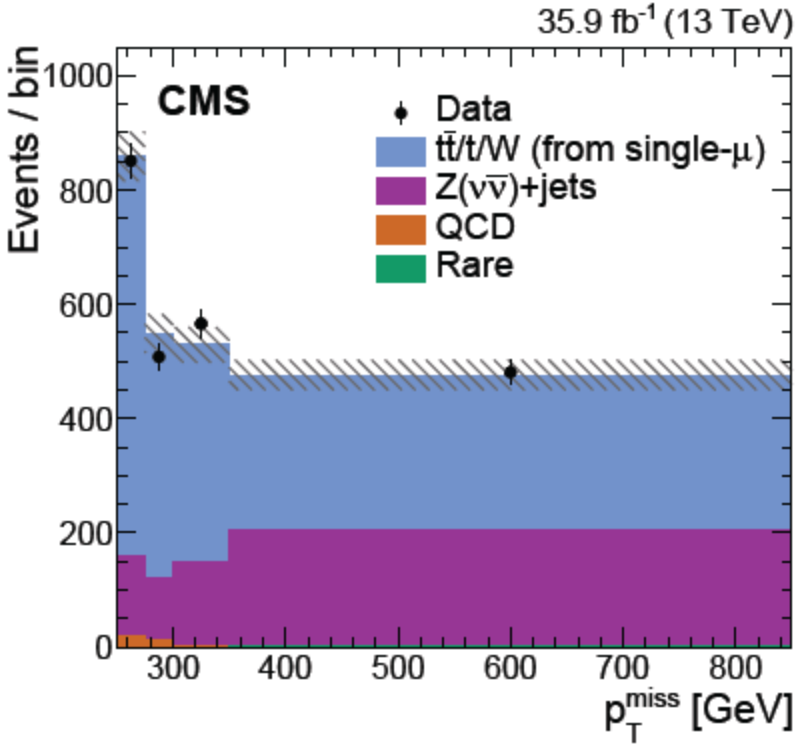
Search bins detail



LL validation

- Data sideband selected using full baseline selection except $Nb \geq 2$, $Nt=0$, and a stricter cut to reduce QCD of $\Delta\phi$ $(pTmiss,\ j1,2,3,4)>0.5$
- Cross-check shows good agreement in both electron and muon channels

Electron Channel



Muon Channel