Search for supersymmetry in all hadronic final states using identified top quarks

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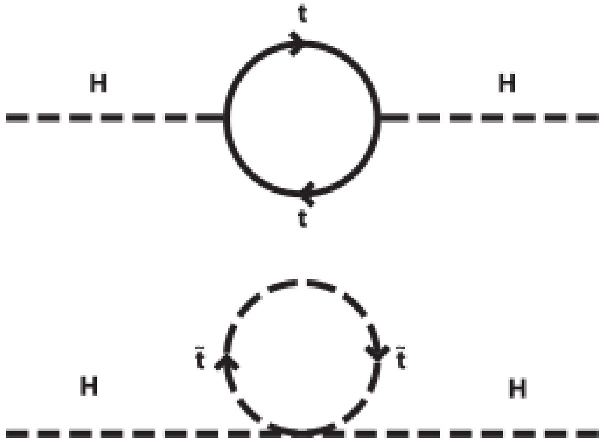
On behalf of CMS collaboration

New Perspectives meeting 2018

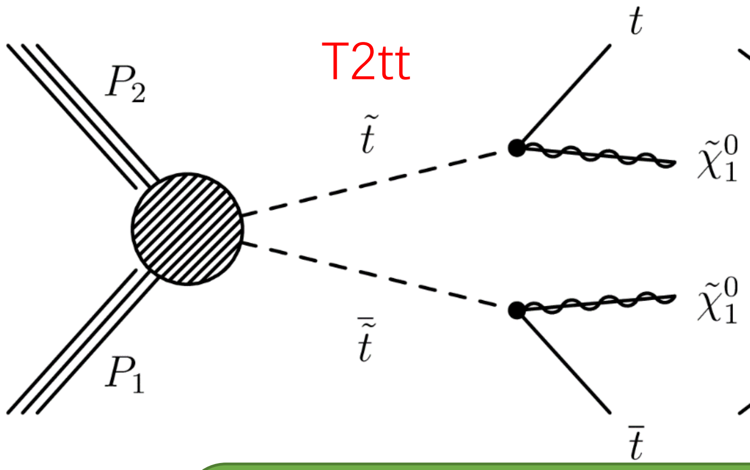
arXiv:1710.11188

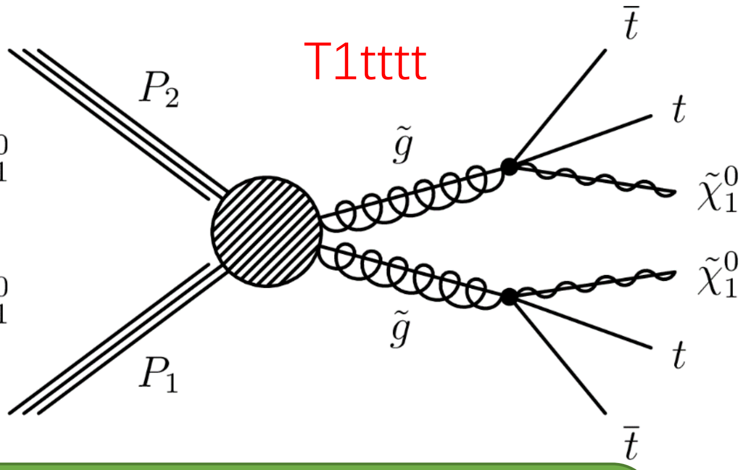
Why sTop?



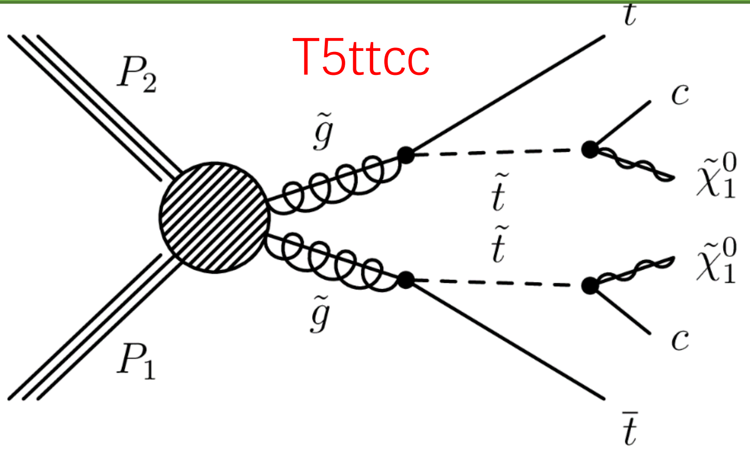
- Top contributes most to the quantum correction of Higgs mass
- Unfortunately, SUSY is broken
- Natural models of SUSY: sTop mass less than a few TeV

Simplified SUSY models





Assuming 100% branching ratio, with tops in final states

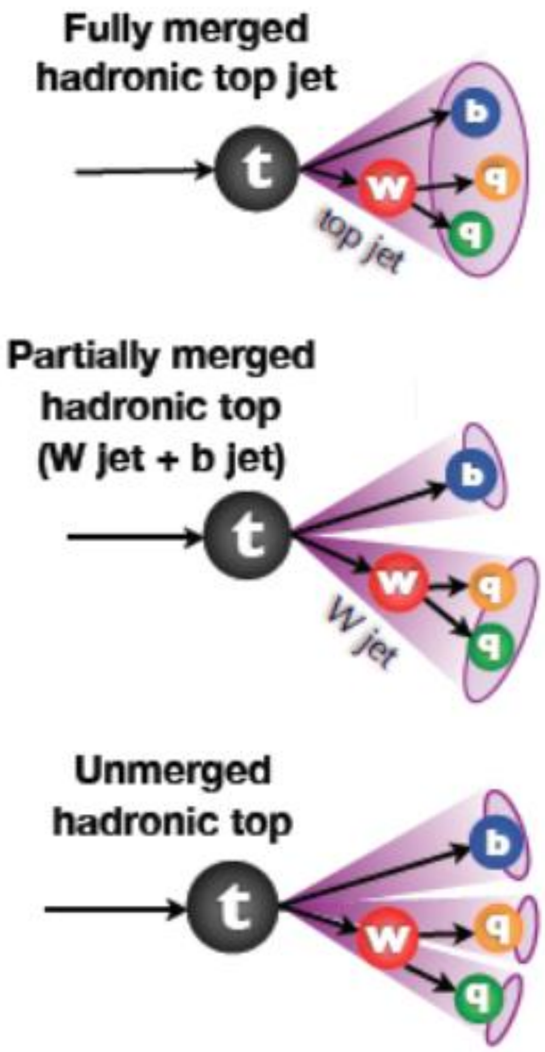


Top tagger - Algorithm

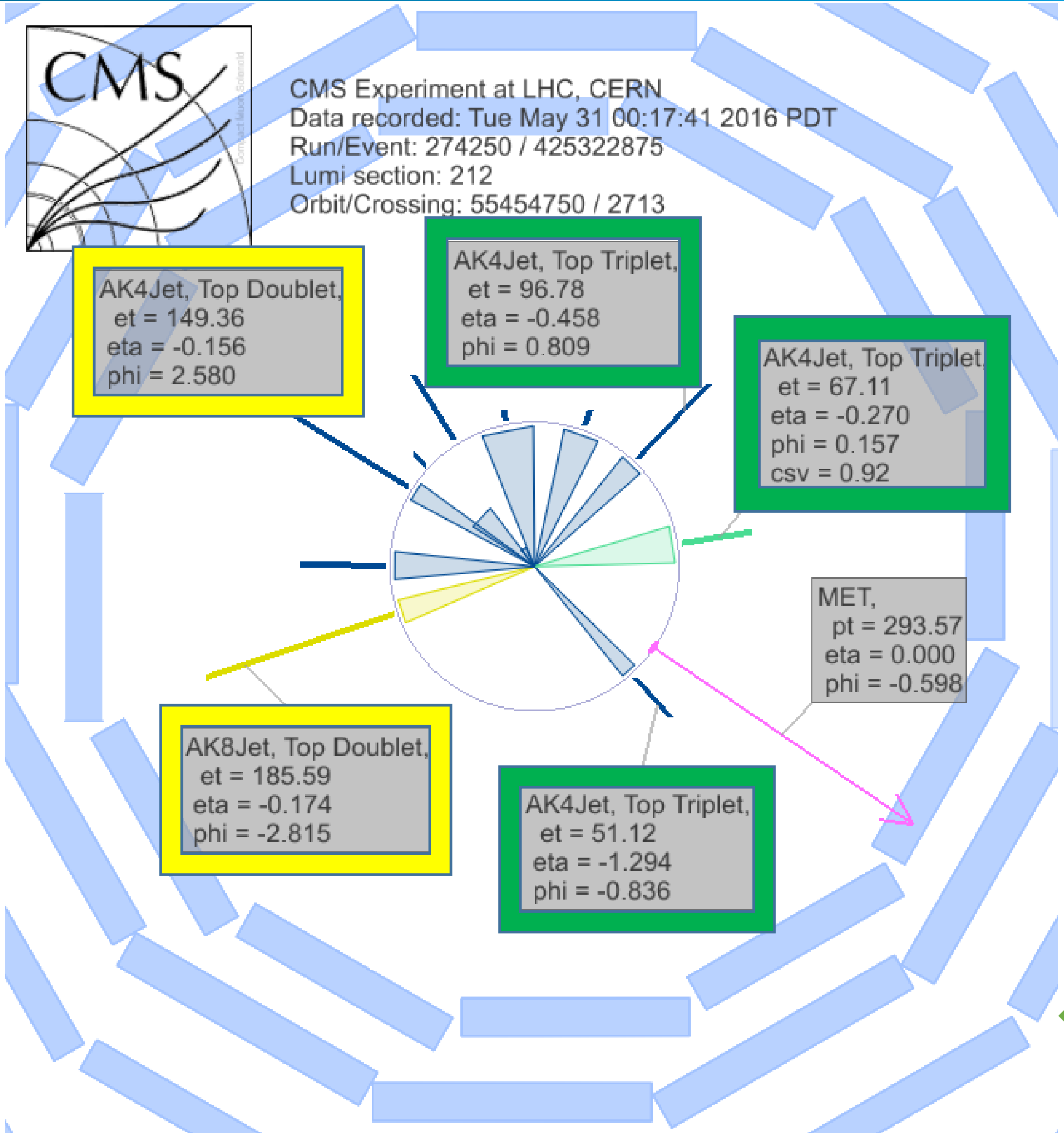
- First tag fully merged tops
- Anti-kt jet with radius parameter = 0.8 (AK8)
- Tagged boosted (p_T > 400) top

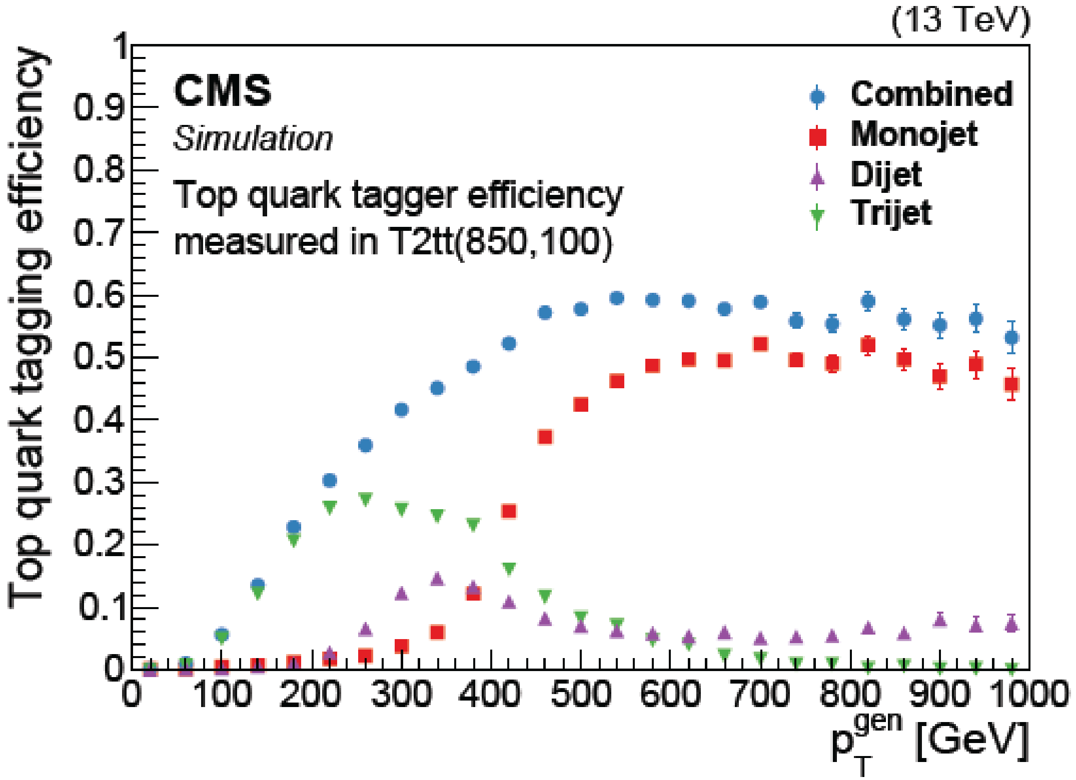
- Then tag partially merged tops
- Tagged AK8 boosted (p_T > 200) W combined with a nearby AK4 jet
- Cone radius R = 1
- Combined mass consistent with top mass (100-250)
- W mass/combined mass consistent with m_W/m_t (0.85 - 1.25)

- Last tag unmerged (resolved) tops
- Combine three resolved AK4 jets (random forest algorithm)
- Cone radius R = 1.5
- No more than one of the three jets can be b tagged
- Combined mass consistent with top mass (100-250)



Top tagger - Performance





CMS event display
A partially merged top (yellow box)
A resolved top (green box)

Baseline and Search Bin

- Jets and p_T^{miss}
- $Njets$ (p_T > 30) ⩾ 4
- Nb ⩾ 1
- p_T^{miss} > 250 GeV
- HT > 300 GeV
- $\Delta\phi$ (j1,2,3, p_T^{miss}) > 0.5, 0.3, 0.3

- 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

Background Estimation

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

Estimated by translation factors method on data

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

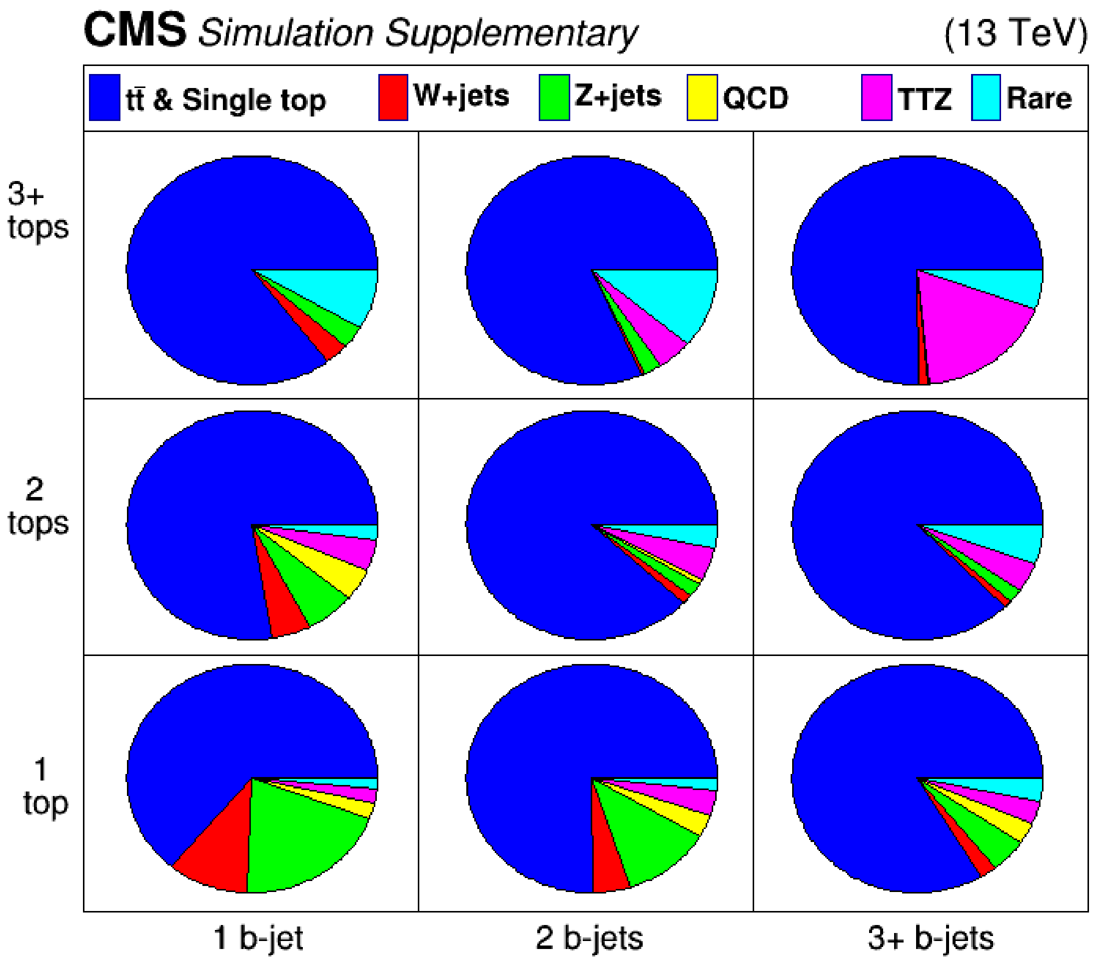
Estimated by data corrected MC

  - QCD (~3%)

Estimated by translation factors method on data

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

Estimated by 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

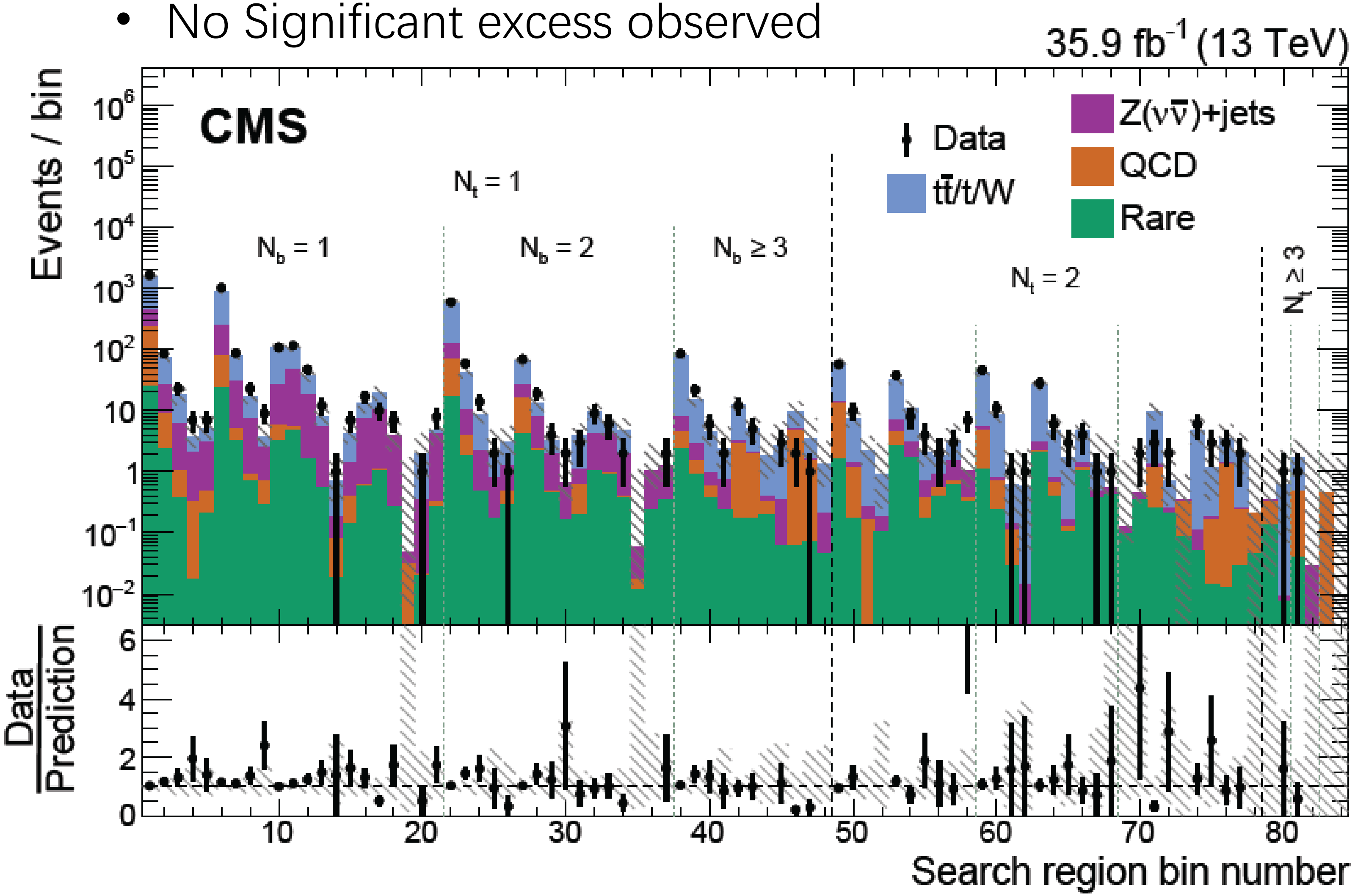
$$\text{TF} = \frac{Nsr}{Ncr}$$

data

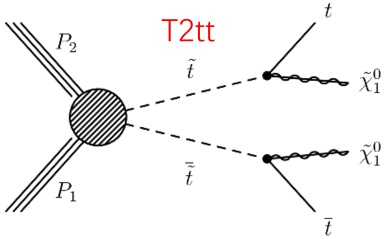
Ncr (data) = number of events in data CR → LL background prediction = Ncr(data) * TF

Results

- Background predictions compared with observed data
- No Significant excess observed

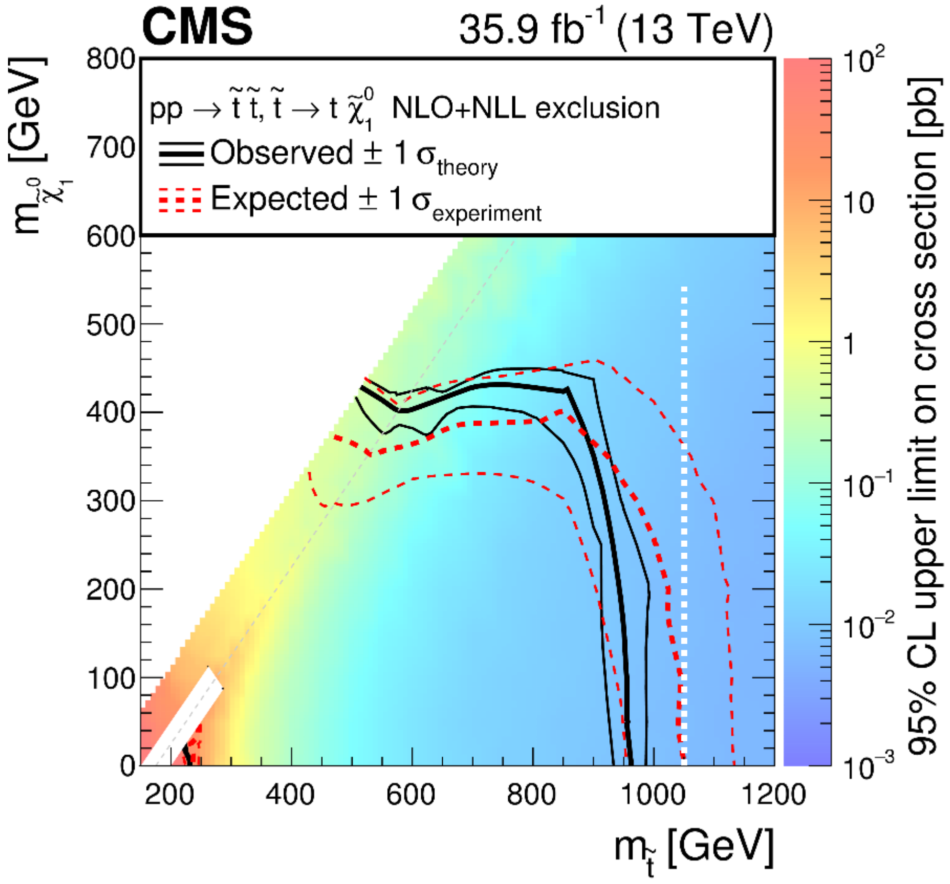


Limits - T2tt



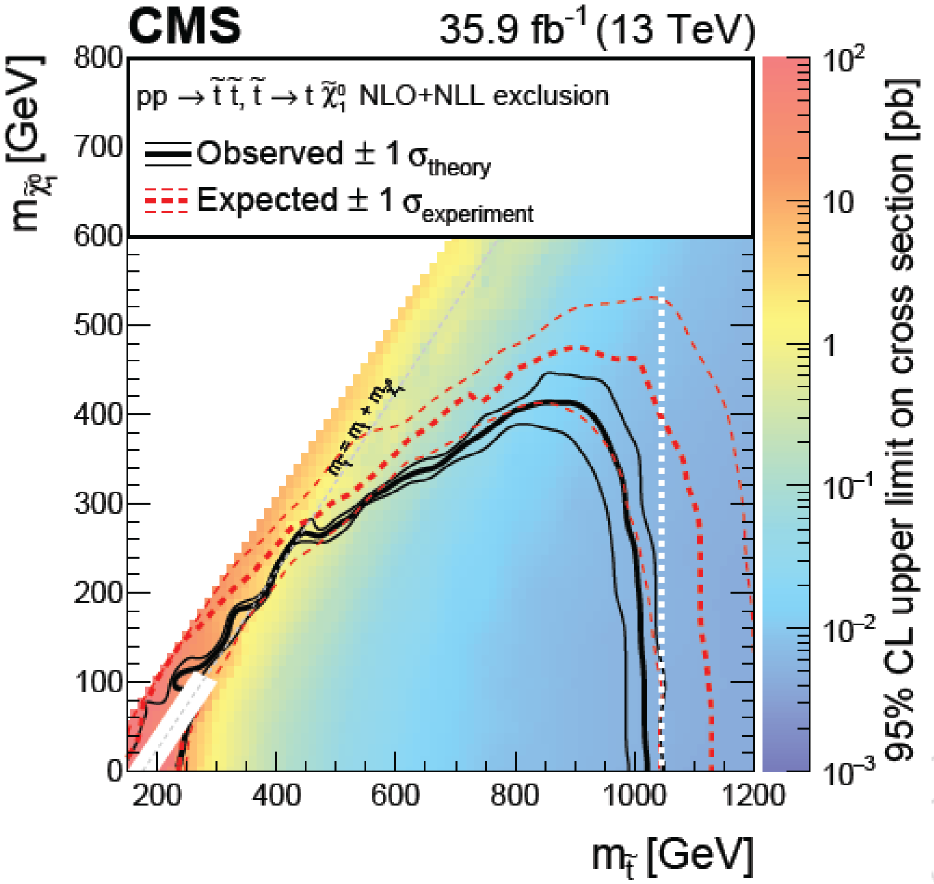
Limits without top tagger

arXiv:1704.07781

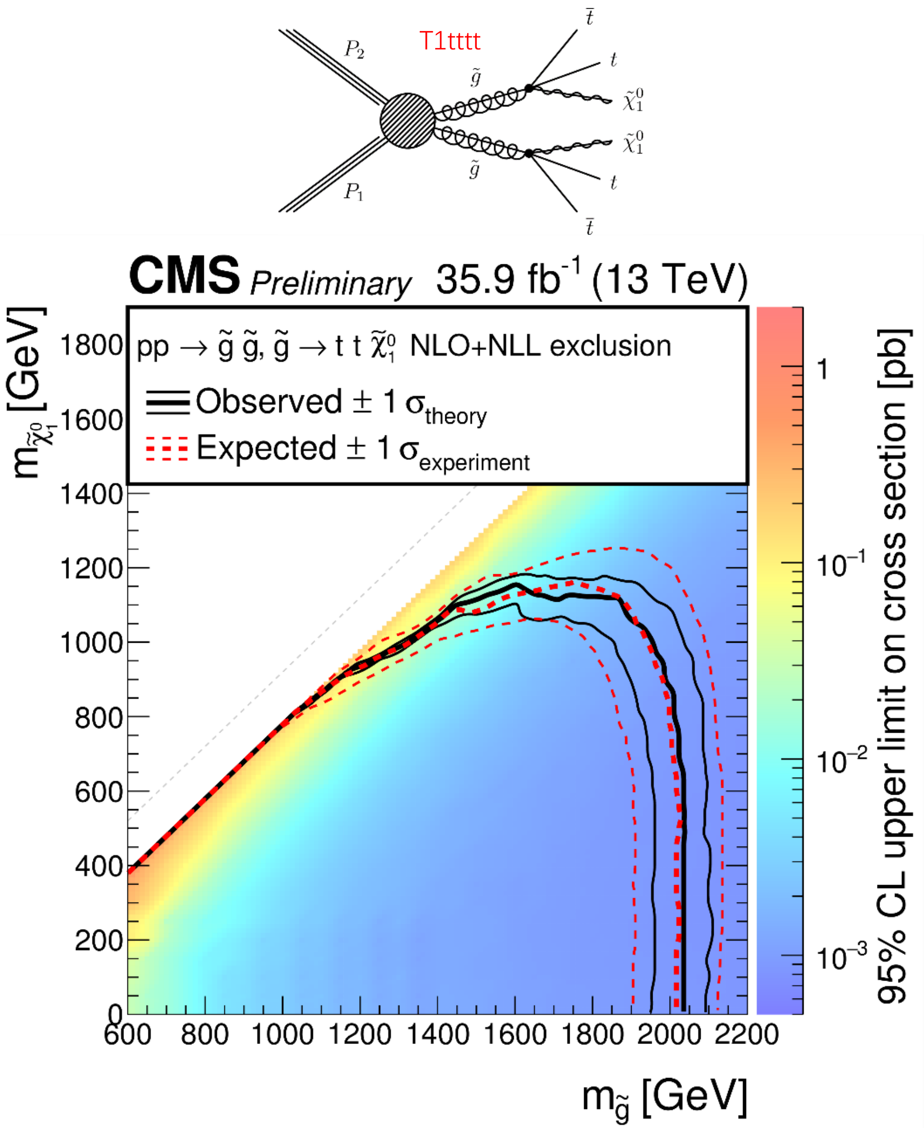


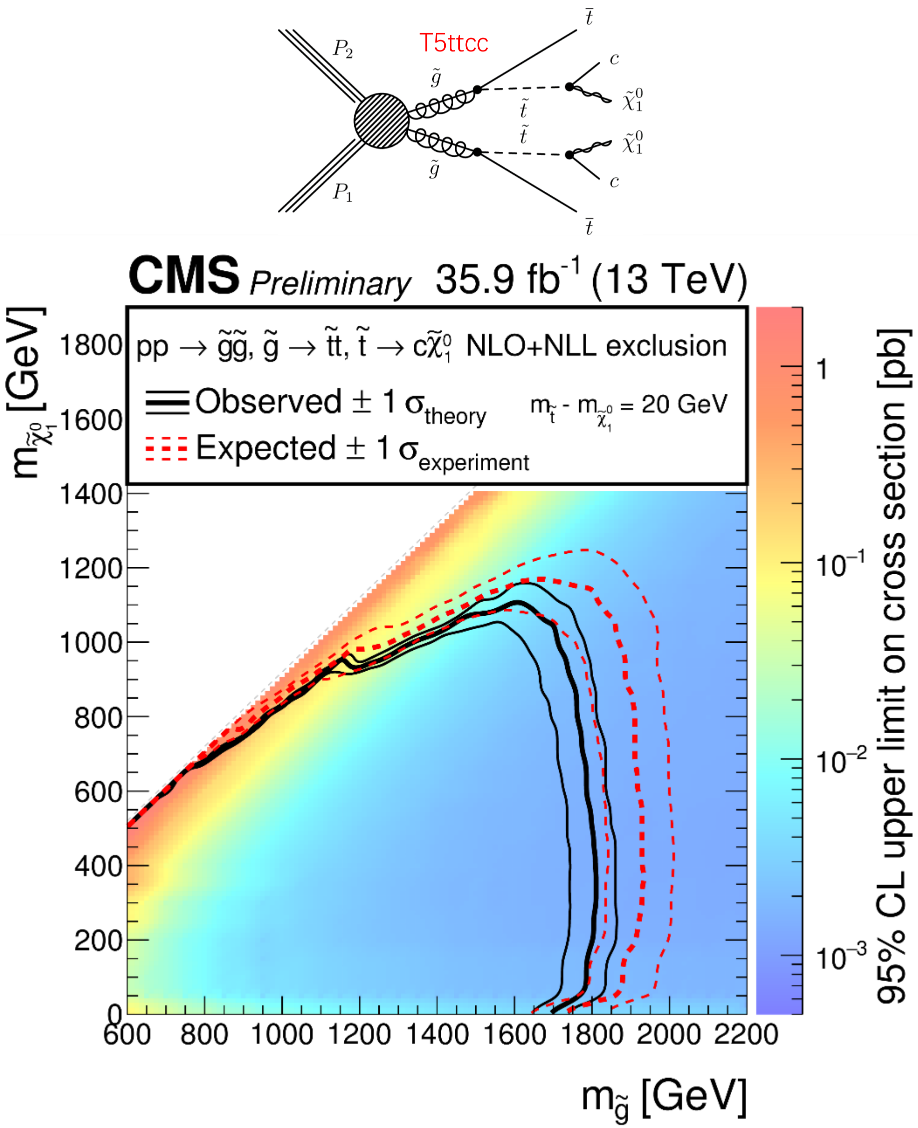
Limits with top tagger

arXiv:1710.11188



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

- Toward CMS Run2 result:

  Even more powerful top tagger with deep neural network

  Search region expansion, especially at compressed region

Thank you for your attention!

Backup slides

Documentation and team member

- Documentation:

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- Team member:

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

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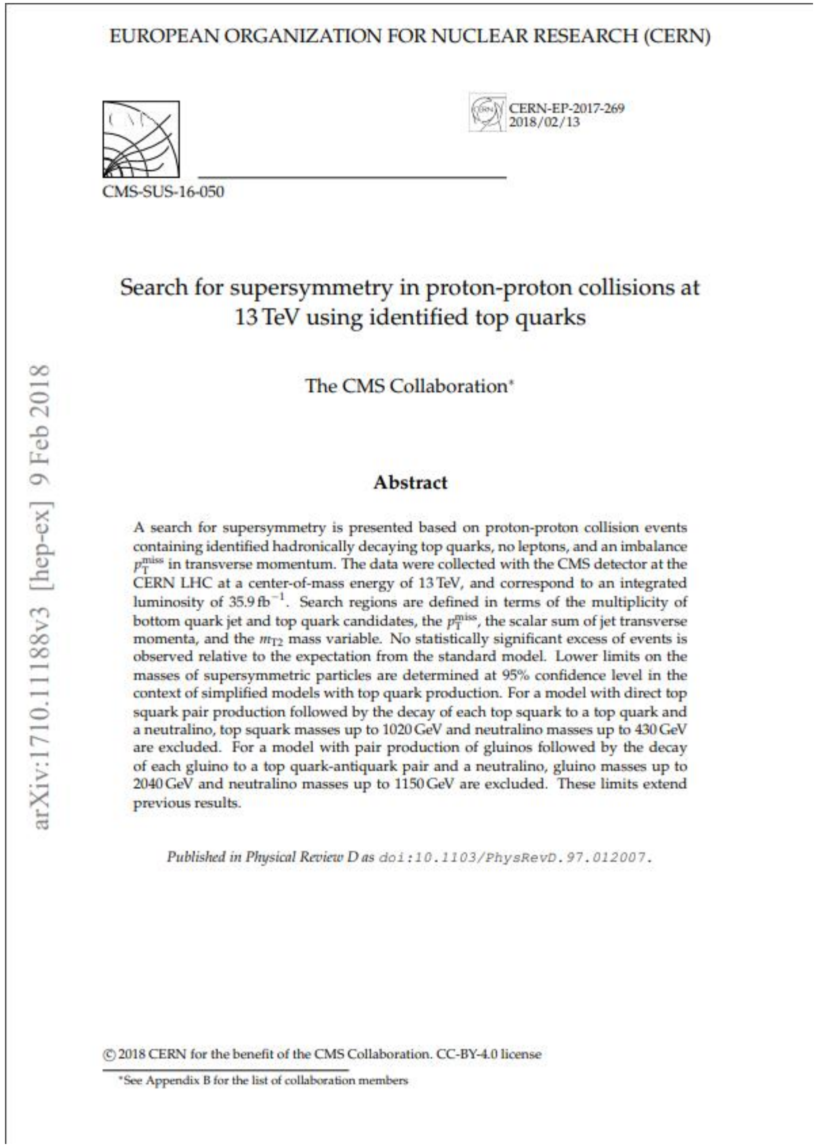
University of Puerto Rico Mayaguez: S. Malik, S. Norberg, A. Abreu



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

The CMS Collaboration*

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.

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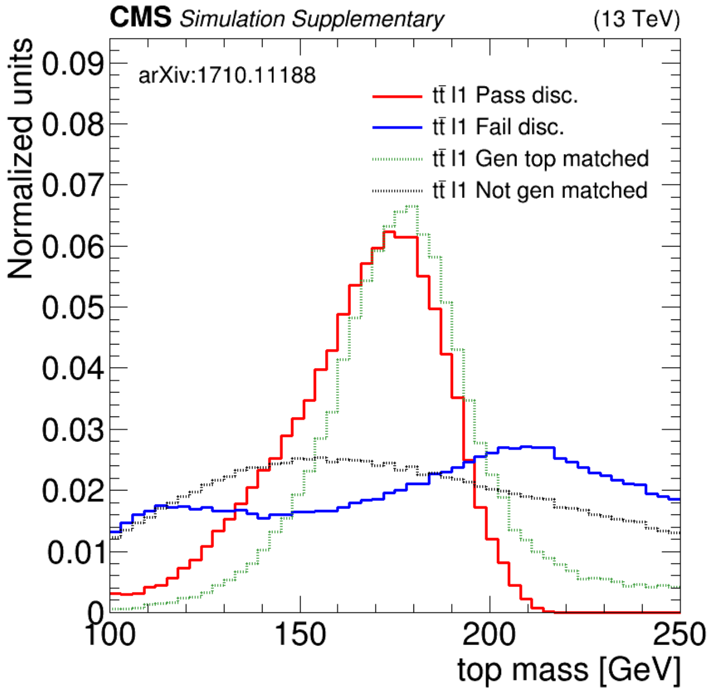
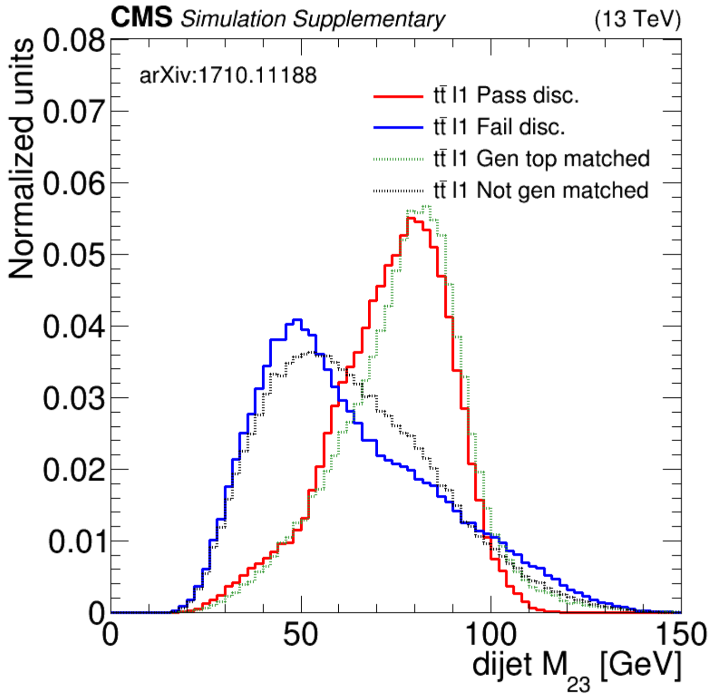
*See Appendix B for the list of collaboration members

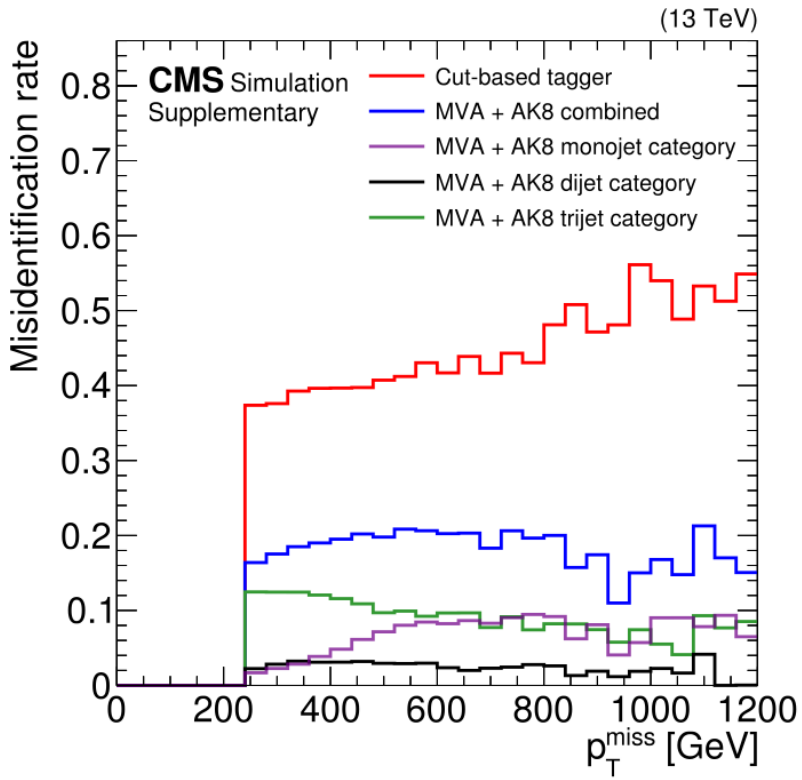
Top tagger - Details

1. mass of the trijet system
2. mass of each dijet combination
3. angular separation and momenta of the jets in the trijet rest frame
4. b tagging discriminator value of each jet
5. quark-versus-gluon-jet discriminator value of each jet

5 input parameters for random forest algorithm







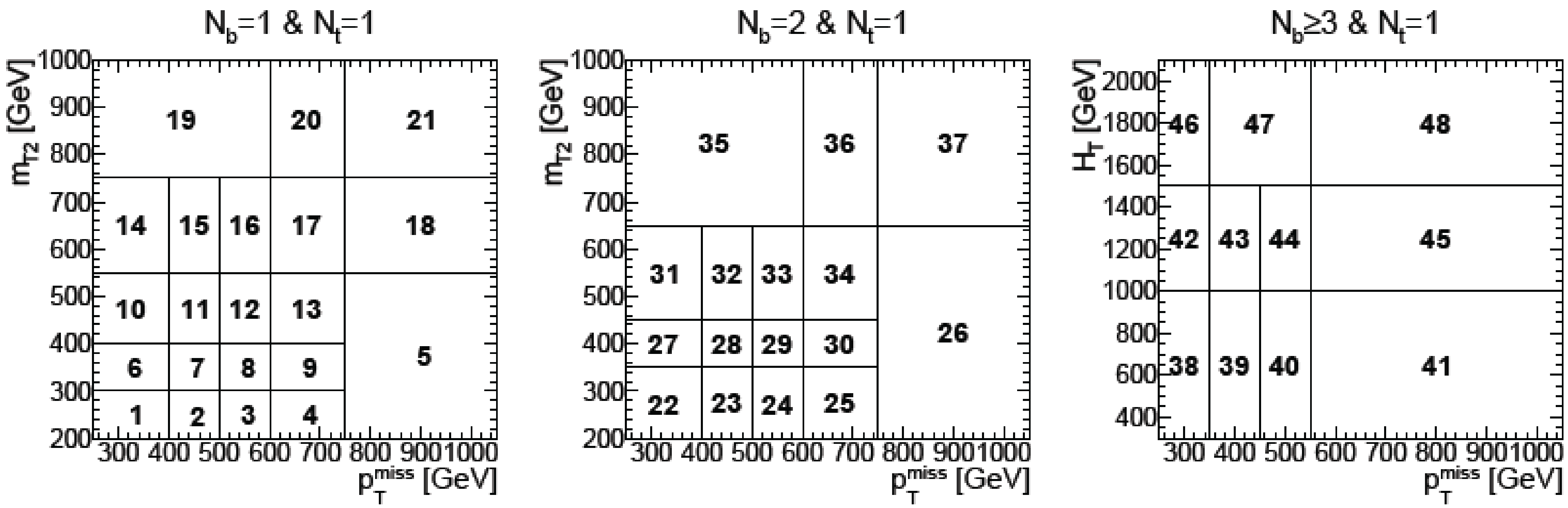
Baseline detail

- Top reconstruction:
- $Nt \geqslant 1$with top tagger
- $MT2$>200GeV
- Jets and $pTmiss$:
- AK4PF jets with CHS:
  $Njets(pT>50) \geqslant 2$
  $Njets(pT>30) \geqslant 4$
- $p_T^{miss}>$ 250 GeV
- $HT>$ 300 GeV
- $\Delta\phi(j1,2,3,\ pTmiss)$ >0.5,0.3,0.3
- $Nb \geqslant 1$(CSVM)

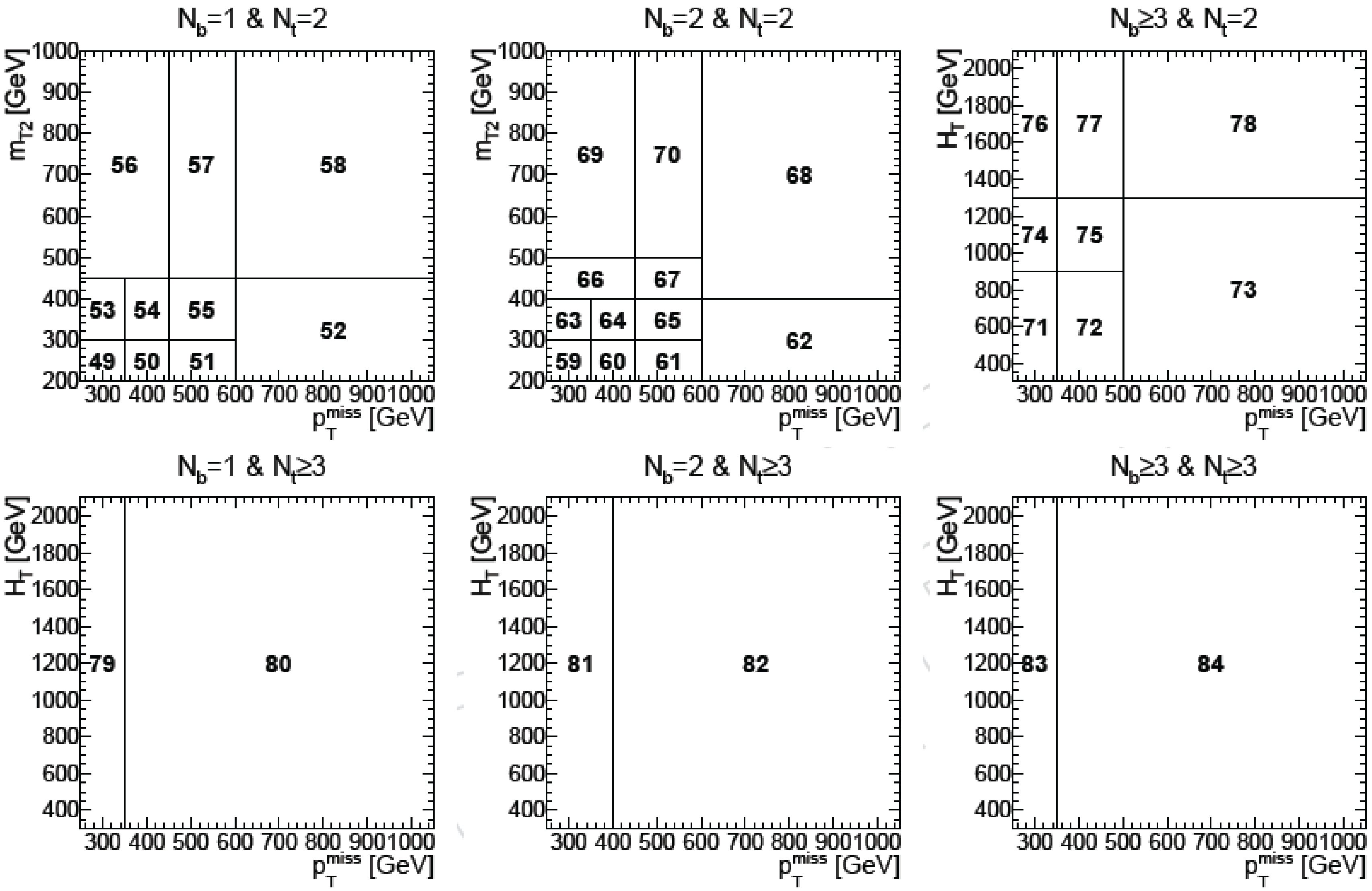
- Lepton/track veto:
- μ veto: pT>10GeV, medium ID && miniISO
- e veto: pT>10GeV, veto ID && miniISO
- IsoTrack: e/μtrack (relIso< 0.2 && pT>5GeV) or πtrack (relIso< 0.1 && pT>10GeV), MtW<100GeV
- Noise cleaning:
- HBHENoiseFilter, HBHENoiseIsoFilter, EcalDeadCellTriggerPrimitiveFilter, GoodVertices, eeBadScFilter, CSCTightHalo2016Filter, badPFMuonFilter, badChargedHadronFilter, LooseJetID+ PFMET/CaloMET<5

Search bins detail

- 84 search bins in Nb, Nt, p_T^{miss}, $MT2/HT$
- Nb, Nt=1,2: Targeting T2tt, each block is binned in p_T^{miss}, $MT2$
- Nb or $Nt \geqslant 3$: Targeting T1tttt, each block is binned in p_T^{miss}, HT



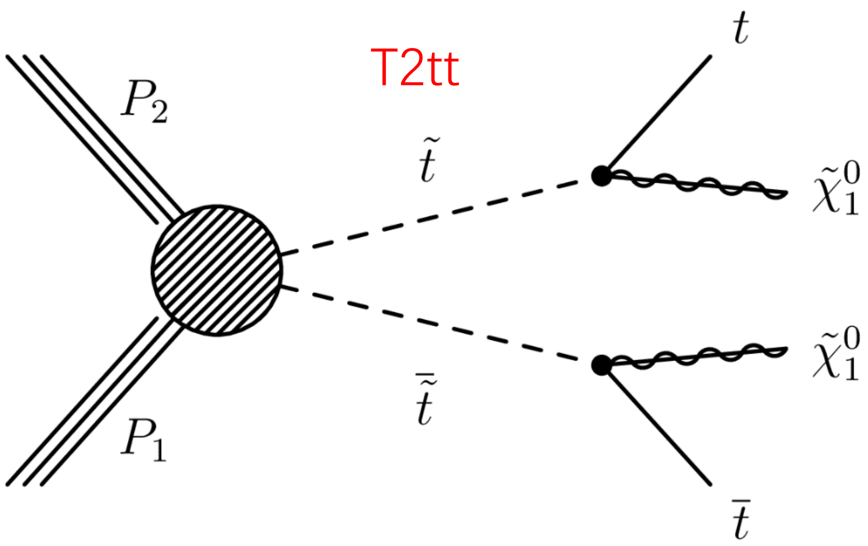
Search bins detail

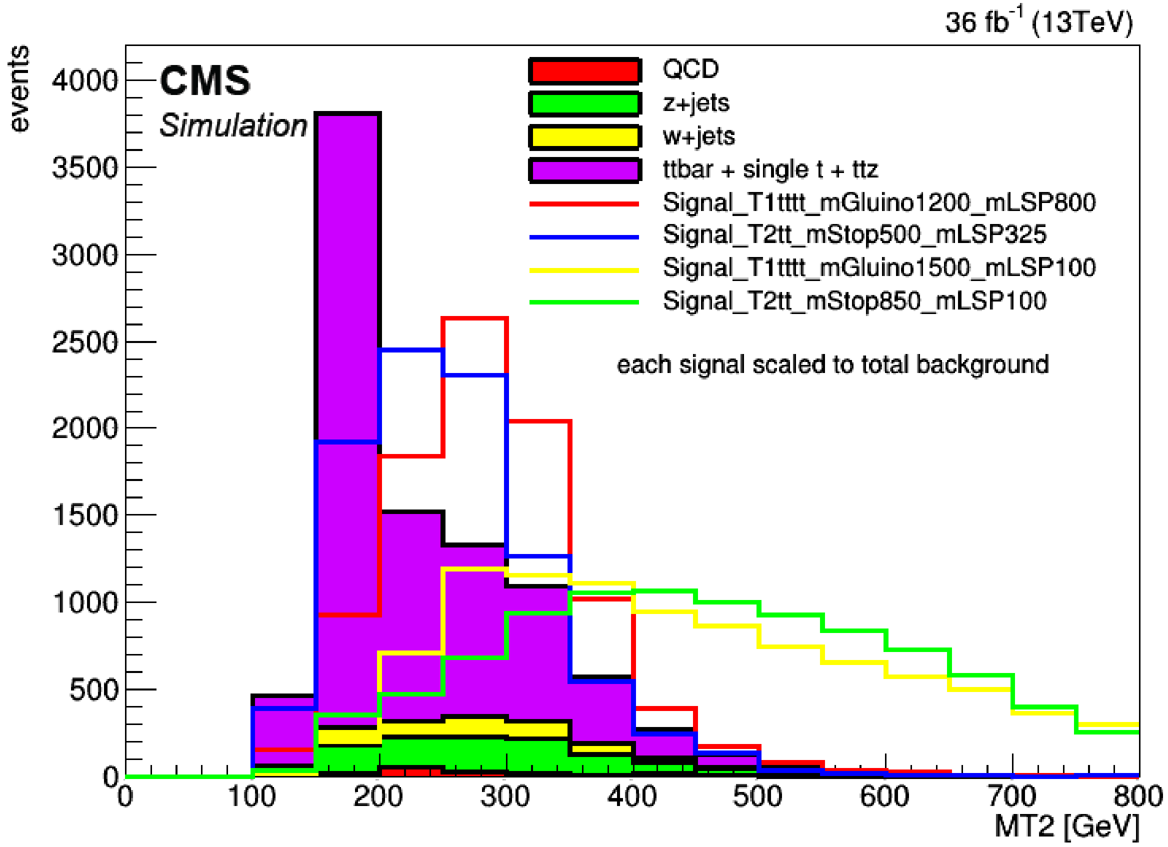


MT2

$$M_{T2}\ (\text{tt}) = \min_{\vec{p}_{T1}^{\,miss}+\vec{p}_{T2}^{\,miss}=\vec{E}_T^{\,miss}} \left(\max\left[M_T(\vec{p}_T^{\,vis1},\vec{p}_{T1}^{\,miss}),\, M_T(\vec{p}_T^{\,vis2},\vec{p}_{T2}^{\,miss})\right]\right)$$

MT2: an extension of MT (transverse mass)





MT2 detail

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

$$\not{p}_T = \mathbf{p}_{T\tilde{\chi}_a} + \mathbf{p}_{T\tilde{\chi}_b}. \tag{9}$$

If $\mathbf{p}_{T\tilde{\chi}_a}$ and $\mathbf{p}_{T\tilde{\chi}_b}$ were obtainable, then one could form two transverse masses, and using the relationship (8) obtain,

$$m_{\tilde{l}}^2 \geq \max\{m_T^2(\mathbf{p}_{Tl^-}, \mathbf{p}_{T\tilde{\chi}_a}), m_T^2(\mathbf{p}_{Tl^+}, \mathbf{p}_{T\tilde{\chi}_b})\} \tag{10}$$

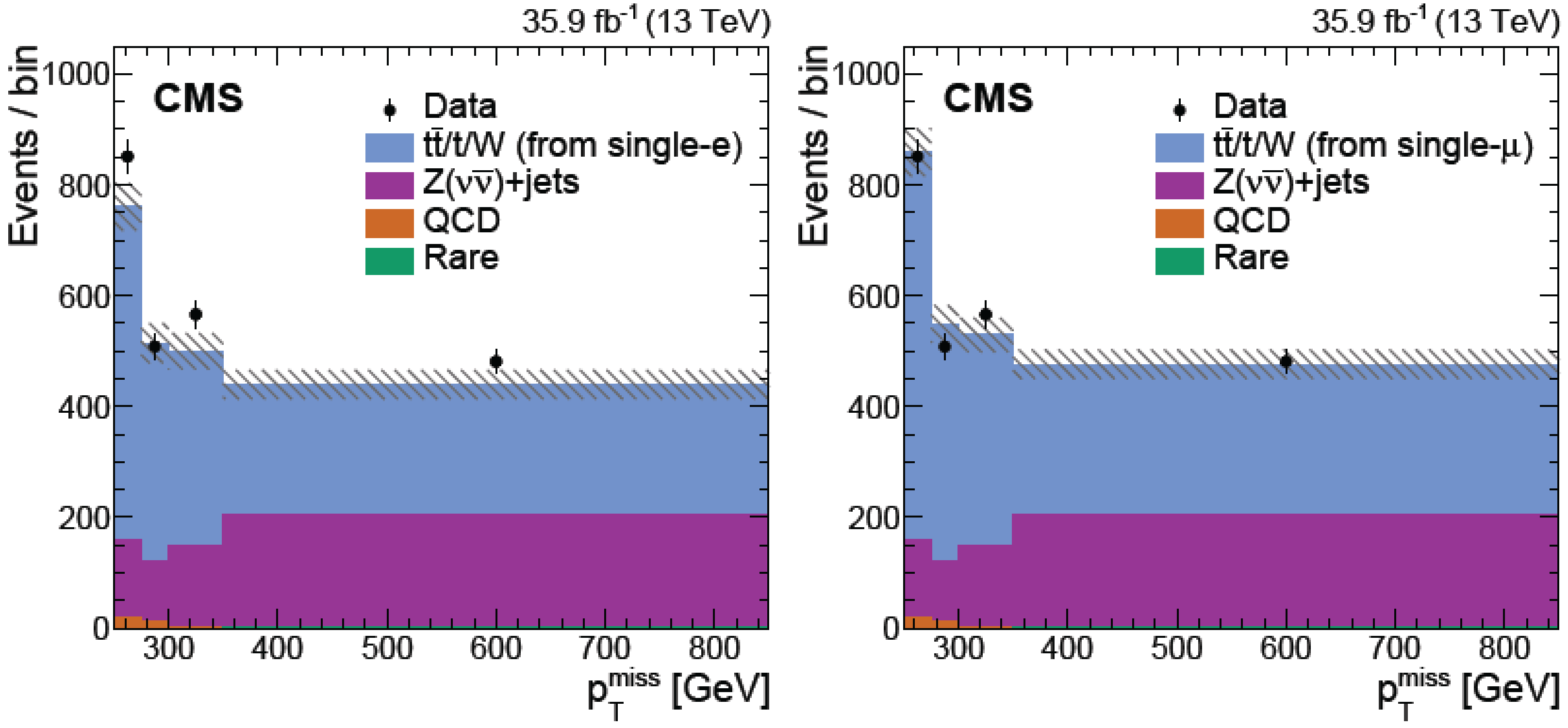
However, not knowing the form of the splitting (9), the best we can say is that:

$$m_{\tilde{l}}^2 \geq M_{T2}^2 \equiv \min_{\not{p}_1 + \not{p}_2 = \not{p}_T} \left[\max\left\{m_T^2(\mathbf{p}_{Tl^-}, \not{p}_1), m_T^2(\mathbf{p}_{Tl^+}, \not{p}_2)\right\}\right] \tag{11}$$

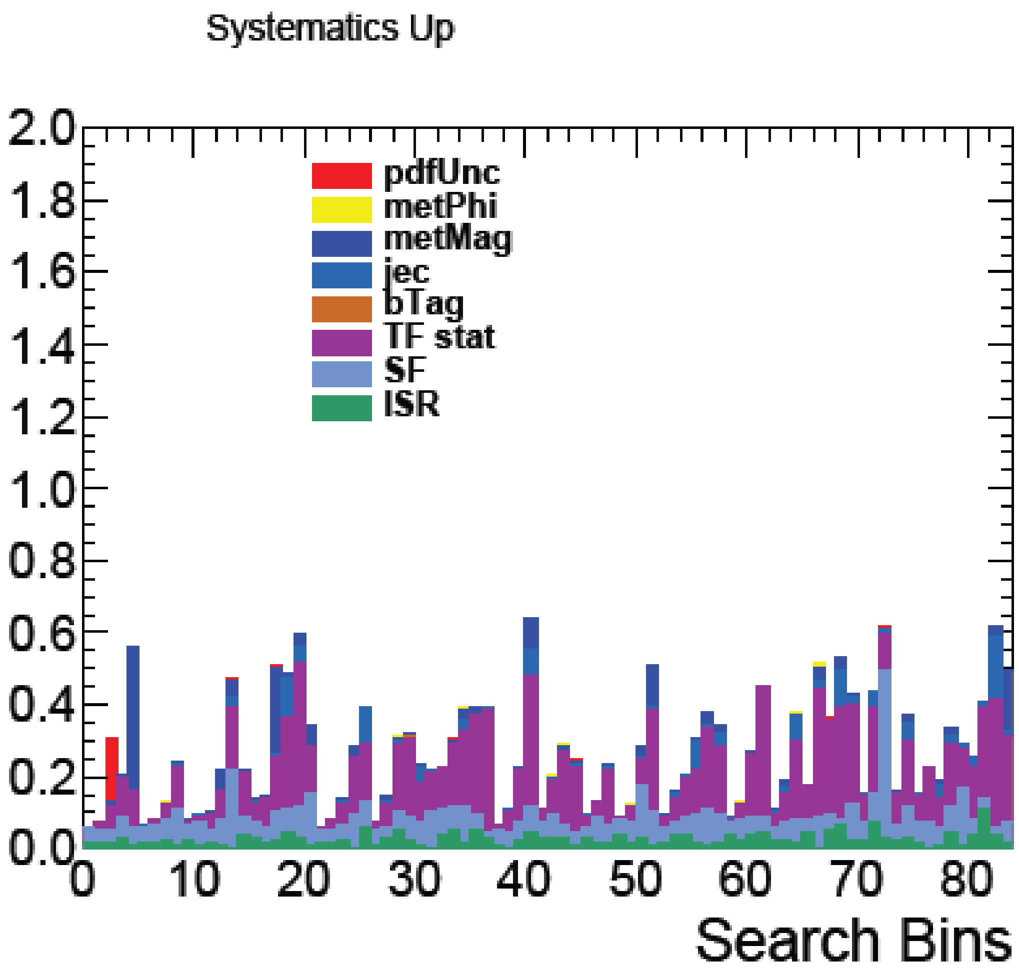
LL validation

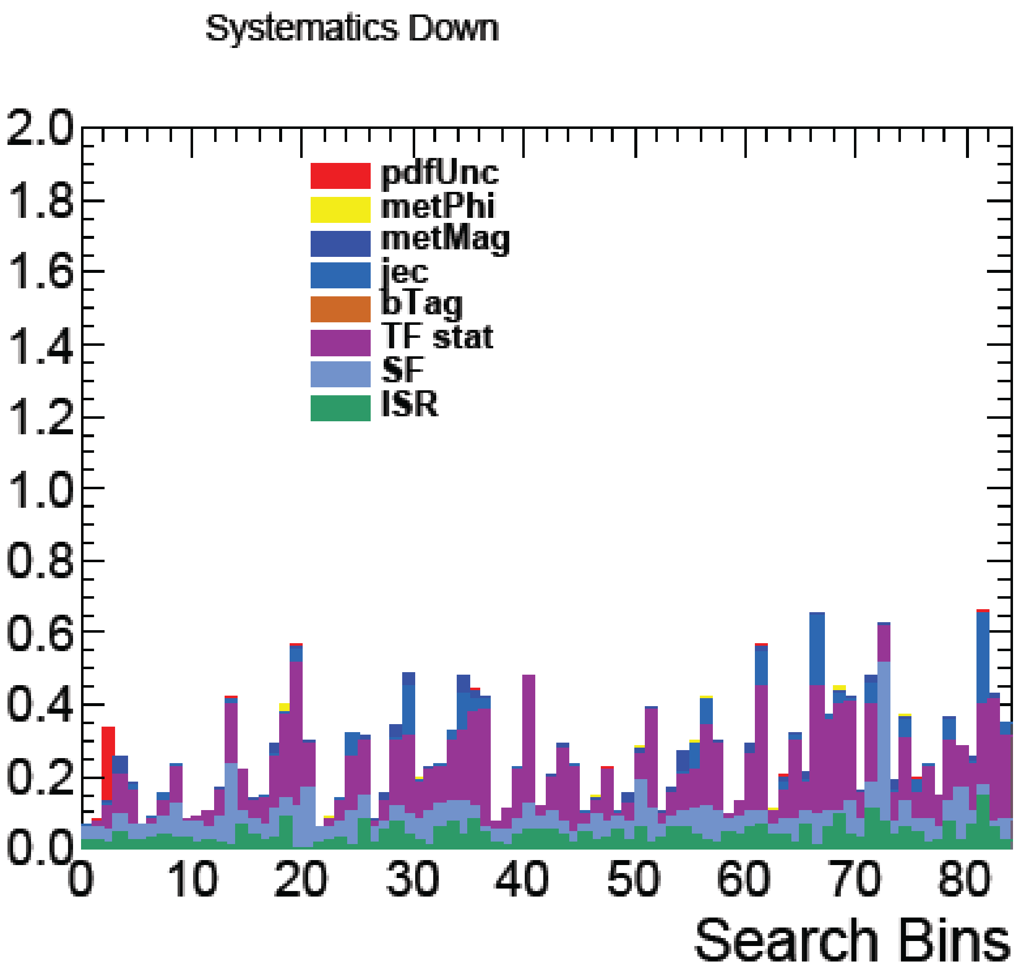
- Data sideband selected using full baseline selection except $Nb \geqslant 2$, $Nt = 0$, and a stricter cut to reduce QCD of $\Delta\phi\ (p_T^{miss}, j1,2,3,4) > 0.5$
- Cross-check shows good agreement in both electron and muon channels

Electron Channel　　Muon Channel



LL systematic uncertainties





Signal systemic uncertainties

Table 35: In T2tt SMS, the signal systematic sources and their typical ranges. The correlation of the uncertainty across signal bins is indicated in the last column.

Source	Typical Values	Correlated?
MC statistics	1-100%	No
Luminosity	2.6%	Yes
Renormalization and factorization scales	0-2.4%	Yes
"ISR" recoil	0-46%	Yes
b-tagging efficiency, heavy flavor	0-17%	Yes
b-tagging efficiency, light flavor	0-17%	Yes
Lepton veto	0-4.7%	Yes
Jet energy scale	0-20%	Yes
MET uncerntainty	0-24%	Yes
Trigger	0-2.6%	Yes
Full/fastsim scale for top reco.	0-19%	Yes
top tagger efficiency data/MC difference	0-14%	Yes