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CMS SUSY and Reinterpretations

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HEPHY
INSTITUT FÜR HOCHENERGIEPHYSIK

Outline

- General principles
- Target Users
- What we provide and how
- Short term developments

The importance of reinterpretations was recognized in CMS-SUSY early on

JHEP

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Search for physics beyond the standard model in opposite-sign dilepton events in pp collisions at $\sqrt{s} = 7$ TeV

The CMS collaboration

Abstract: A search is presented for physics beyond the standard model (SM) in final states with opposite-sign isolated lepton pairs accompanied by hadronic jets and missing transverse energy. The search is performed using LHC data recorded with the CMS detector, corresponding to an integrated luminosity of 34 pb^{-1}. No evidence for an event yield beyond SM expectations is found. An upper limit on the non-SM contribution to the signal region is deduced from the results. This limit is interpreted in the context of the constrained minimal supersymmetric model. Additional information is provided to allow testing the exclusion of specific models of physics beyond the SM.

Guiding Principles

- Facilitate reinterpretations of CMS SUSY results by outsiders
- Do not pretend to aim for perfection.
  - Factor of ~ 2 is good enough.
- Minimize burden on CMS analysts.
  - Keep it simple
- Re-interpreters are ultimately responsible for the results. Not CMS.

Target User

- Phenomenologist with BSM MC model processed through hadronization.
- Able to cluster jets with FastJet package.
- Uses some fast simulation package (PGS, Delphes..). Or smears things by hand. Up to him/her.
- No need to simulate pileup.
- Knows how to use Root.

User's goals

- Ability to estimate approximate event yield of BSM model for CMS selection.
- Compare with data yield and background predictions from CMS paper.
- Decide whether BSM model is excluded or not.
- (Works for excesses too)

What we provide on public webpages

- Well-defined kinematical requirements.
- In searches with leptons/photons:
  - efficiencies vs. P_T and possibly η.
- In searches with b-tags:
  - efficiency for tagging b-jets vs. P_T.
- If we use complex kinematical variables:
  - standalone code to calculate them.
- Cut-flow tables for a few well-defined benchmarks.
- Acceptance maps (when they make sense)
- Some analyses may be too complicated for this
- Also HepData
  - Only after acceptance by journal

What we do not provide (in the name of simplicity)

- Jet, lepton, photons, MET resolutions
  - These are usually not so important, and if they are, re-interpretations by outsiders are likely problematic (use judgment)
- Efficiencies or over-efficiencies for lepton vetoes, light quark b-tagging probability, fake lepton probabilities
  - These are 2nd order effects (or should be, if the right search is picked for a given BSM model).
  - They can be very important for BG estimates. But we provide those.

Experience from Run 1 and Run 2 developments

- In Run 1 this procedure was followed for many but not all analyses. Not always in a consistent way.
- Starting with the Moriond 2017 round of analyses:
  - Require all analyses to provide this information
    - Unless it is not possible for some (good) reason
  - Centralize and standardize the way that the information is provided (already started for ICHEP 2016)

Compact Muon Solenoid
LHC, CERN

Visit us: CMS Public Website, CMS Physics ; Contact us: CMS Publications Committee

CMS-PAS-SUS-16-026

Search for electroweak production of charginos and neutralinos in the WH final state at 13 TeV

CMS Collaboration

August 2016

Abstract: A search is performed for beyond the standard model physics in events with a leptonically-decaying W boson, a Higgs boson decaying to a pair of b-quarks, and missing transverse energy, using 12.9 fb^{-1} of data recorded by CMS in 2016 at $\sqrt{s} = 13$ TeV. This signature is predicted to occur, for example, in supersymmetric models from electroweak production of gauginos. The observed data are in agreement with the standard model prediction. The results are used to set cross section limits on chargino-neutralino production in a simplified model of supersymmetry with the decays $\tilde{\chi}_1^{\pm} \rightarrow W\tilde{\chi}_1^0$ and $\tilde{\chi}_2^0 \rightarrow H\tilde{\chi}_1^0$.

Links: CDS record (PDF) ; CADI line (restricted) ;

Figures & Tables | Summary | References | CMS Publications

Additional information on efficiencies needed for reinterpretation of these results are available here.

Figures

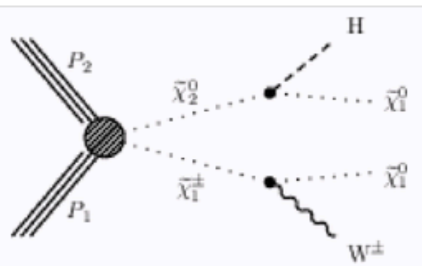

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Figure 1:
Feynman diagram of the SUSY simplified model targeted by this analysis: chargino-neutralino production with the chargino decaying to the W boson and the LSP, while the second neutralino decays to the Higgs boson and the LSP.

Not all ICHEP analysis page have this link.

CMS SUSY Results: Objects Efficiency

- ICHEP 2016
  - Light Leptons Selection Efficiency
  - Hadronic Tau identification efficiency
  - B-tagging Efficiency
  - Photon Selection Efficiency

ICHEP 2016

In the following the representative object selection efficiencies for the SUSY 2016 analyses (using 2016 data) are reported.

Light Leptons Selection Efficiency

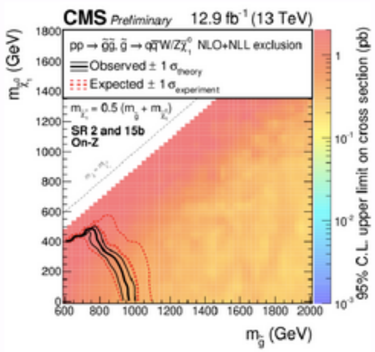
Representative Muon and Electron efficiencies for the WPs of the identification techniques used in SUS-16 analyses:

- only the analyses with at least one light lepton in the final state are considered and only the efficiency for the signal-lepton selections is reported (no veto selections);
- the efficiency refers to the reconstruction + identification + isolation + vertexing requirements for generator-level leptons from W decay in a simulated sample of ttbar events;
- the efficiency is corrected with the corresponding data/simulation scale factors extracted from 2016 data, using Tag-and-probe techniques.

CADI	Analysis	Muon pT and eta	Muon Selection Efficiency vs (pT, eta)	.root file	El pT and eta	Electron Selection Efficiency vs (pT, eta)	.root file
SUS-16-019	One Lepton Strong (Δφ)	25, 2.4	eff	eff	25, 2.5	eff	eff
SUS-16-020	Same-Sign dilepton Strong	10, 2.4	eff	eff	15, 2.5	eff	eff
SUS-16-021	Opposite-Sign dilepton Strong and	20, 2.4	eff	eff	20, 2.4	eff	eff

Additional Figures

CMS-PAS-SUS-16-022



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Additional Figure 7-b:
Excluded region at 95% confidence in the $m(\tilde{\chi}_0)$ versus $m(\tilde{g})$ plane for the T1tttt (a) and T5qqqqWZ (b) simplified model using only the most sensitive signal regions. For T1tttt the limit is obtained by statistical combination of off-Z signal region 13 and 15. Almost the same sensitivity as with the combination of all 32 signal regions can be achieved. For T5qqqqWZ on-Z signal region 2 and 15b are combined. A similar sensitivity as with the combination of all signal regions can be achieved, only very close to the diagonal less mass points can be excluded. The color scale indicates the excluded cross section at a given point in the mass plane. The excluded regions are to the left and below the observed and expected limit curves.

E.g.: sensitivity with reduced number of signal regions

Additional Tables

$m_{\tilde{g}}/m_{\tilde{\chi}_1^0}$ (GeV) selection	T1tttt (1200/100)	T1tttt (1200/700)
≥ 3 leptons, $p_T > 10$ GeV	$18.6 \pm 0.6\ ^{+6.8}_{-5.6}$	$17.9 \pm 0.6\ ^{+6.5}_{-5.4}$
$m_{\ell\ell} \geq 12$ GeV	$18.6 \pm 0.6\ ^{+6.8}_{-5.6}$	$17.9 \pm 0.6\ ^{+6.5}_{-5.4}$
lepton p_T selection	$18.6 \pm 0.6\ ^{+6.8}_{-5.6}$	$17.9 \pm 0.6\ ^{+6.5}_{-5.4}$
Z / γ^* veto	$15.6 \pm 0.5\ ^{+5.7}_{-4.8}$	$14.4 \pm 0.5\ ^{+5.3}_{-4.4}$
$N_{jets} \geq 2$	$15.6 \pm 0.5\ ^{+5.7}_{-4.7}$	$14.3 \pm 0.5\ ^{+5.2}_{-4.4}$
$E_T^{miss} \geq 50$ GeV	$15.3 \pm 0.5\ ^{+5.6}_{-4.7}$	$13.8 \pm 0.5\ ^{+5.1}_{-4.2}$

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Additional Table 1:
Evolution of signal yields along the cut flow of the off-Z baseline selection for selected mass points of the T1tttt SUSY bench mark model. The yields are normalized to an integrated luminosity of $\mathcal{L} = 12.9$ fb^{-1}.

E.g.: cut flow tables

$m_{\tilde{g}}/m_{\tilde{\chi}_1^0}$ (GeV) selection	T5qqqqWZ (1000/100)	T5qqqqWZ (800/500)
≥ 3 leptons, $p_T > 10$ GeV	$16.8 \pm 0.8\ ^{+6.1}_{-5.1}$	$58.1 \pm 3.0\ ^{+22.3}_{-18.6}$
$m_{\ell\ell} \geq 12$ GeV	$16.8 \pm 0.8\ ^{+6.1}_{-5.1}$	$58.1 \pm 3.0\ ^{+22.3}_{-18.6}$
lepton p_T selection	$16.8 \pm 0.8\ ^{+6.1}_{-5.1}$	$58.1 \pm 3.0\ ^{+22.3}_{-18.6}$
Z / γ^* selection	$15.0 \pm 0.7\ ^{+5.5}_{-4.6}$	$54.3 \pm 2.9\ ^{+20.9}_{-17.4}$
$N_{jets} \geq 2$	$15.0 \pm 0.7\ ^{+5.5}_{-4.6}$	$53.0 \pm 2.9\ ^{+20.4}_{-17.0}$
$E_T^{miss} \geq 50$ GeV	$14.7 \pm 0.7\ ^{+5.4}_{-4.5}$	$50.5 \pm 2.8\ ^{+19.4}_{-16.1}$

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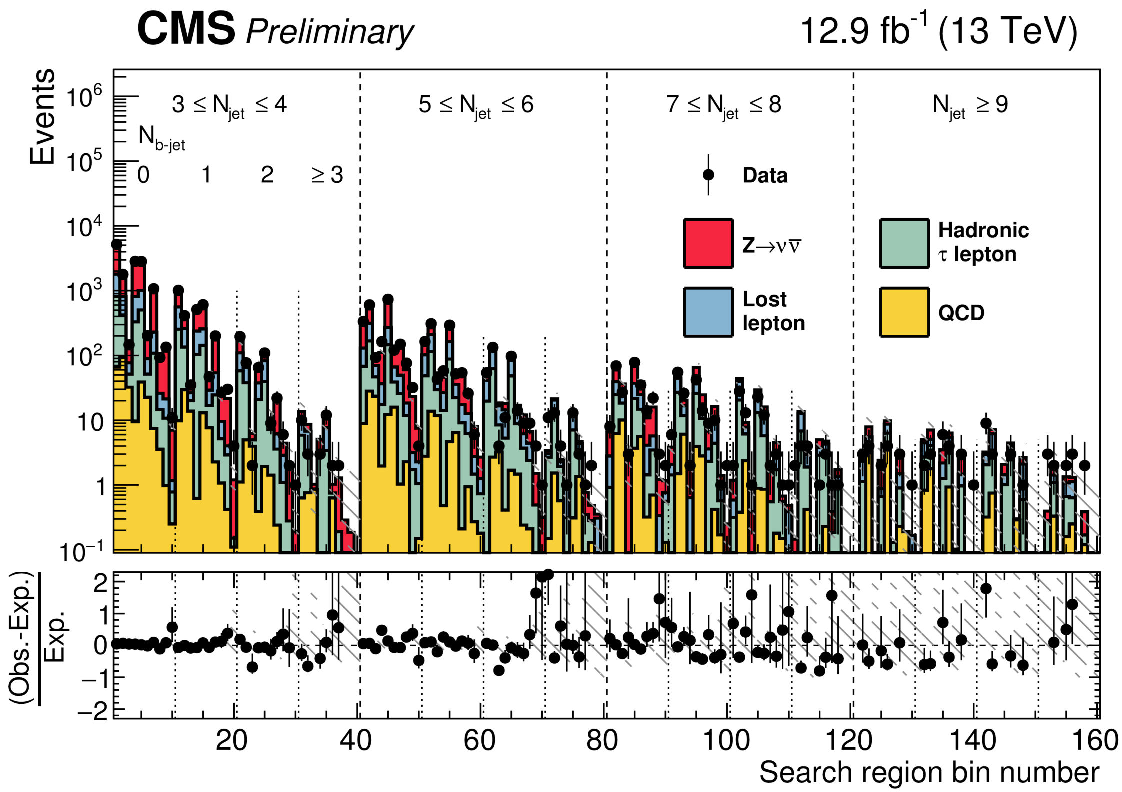
Additional Table 2:
Evolution of signal yields along the cut flow of the on-Z baseline selection for selected mass points of the T5qqqqWZ SUSY bench mark model. The yields are normalized to an integrated luminosity of $\mathcal{L} = 12.9$ fb^{-1}.

Additional material (on the same page) complements information where deemed useful.

Complications: Many Exclusive Signal Regions

- Run 2 analyses use many exclusive bins



Jets + MET
CMS-SUS-PAS-16-014

- Improves the coverage
- Re-interpretations are problematic

Solution 1

- Define aggregated inclusive regions
- Re-interpretation would pick “best” region for particular BSM model
- Some loss of sensitivity, but easy for outsiders

Jets + MET
CMS-SUS-PAS-16-014

Region	N_{jet}	$N_{\text{b-jet}}$	H_{T} [GeV]	$H_{\text{T}}^{\text{miss}}$ [GeV]	Lost-e/μ	$\tau \to$ had	$Z \to \nu\bar{\nu}$	QCD	Total Pred.	Obs.
1	3+	0	500+	500+	$182.17^{+9.94+19.65}_{-9.68-18.69}$	$163.88^{+7.82+19.36}_{-7.60-19.45}$	$1134.31^{+20.69+90.69}_{-20.69-79.36}$	$17.28^{+1.61+11.45}_{-0.95-11.45}$	$1497.64^{+27.31+95.59}_{-26.97-84.82}$	1614
2	3+	0	1500+	750+	$1.98^{+1.33+0.50}_{-0.73-0.46}$	$1.86^{+1.11+0.52}_{-0.63-0.52}$	$11.50^{+2.25+1.92}_{-2.22-1.54}$	$0.53^{+0.15+0.34}_{-0.09-0.34}$	$15.87^{+3.32+2.06}_{-2.60-1.75}$	18
3	5+	0	500+	500+	$39.02^{+3.87+4.84}_{-3.57-4.63}$	$42.07^{+3.61+3.99}_{-3.23-4.00}$	$197.65^{+8.66+16.25}_{-8.64-14.36}$	$5.07^{+1.33+2.94}_{-0.51-2.94}$	$283.80^{+11.52+17.92}_{-11.01-15.72}$	306
4	5+	0	1500+	750+	$1.60^{+0.96+0.46}_{-0.61-0.42}$	$1.33^{+0.97+0.49}_{-0.56-0.49}$	$5.66^{+1.56+1.25}_{-1.51-1.00}$	$0.28^{+0.15+0.20}_{-0.08-0.20}$	$8.87^{+2.48+1.42}_{-1.92-1.24}$	7
5	9+	0	1500+	750+	$0.17^{+0.43+0.17}_{-0.17-0.00}$	$0.00^{+0.46+0.00}_{-0.00-0.00}$	$0.00^{+0.37+0.00}_{-0.00-0.00}$	$0.00^{+0.07+0.00}_{-0.00-0.00}$	$0.17^{+0.97+0.17}_{-0.17-0.00}$	1
6	3+	2+	500+	500+	$12.43^{+4.95+1.54}_{-2.66-1.47}$	$15.82^{+3.26+1.56}_{-1.96-1.57}$	$33.11^{+3.99+5.75}_{-3.90-5.64}$	$1.93^{+1.79+1.24}_{-0.38-1.24}$	$63.29^{+9.30+6.31}_{-6.06-6.17}$	71
7	3+	1+	750+	750+	$3.93^{+3.27+0.81}_{-1.14-0.60}$	$6.07^{+2.60+0.96}_{-1.30-0.96}$	$30.00^{+2.76+4.56}_{-2.51-3.69}$	$1.43^{+1.55+1.05}_{-0.31-1.05}$	$41.43^{+6.67+4.80}_{-3.51-4.07}$	54
8	5+	3+	500+	500+	$0.75^{+2.14+0.22}_{-0.44-0.22}$	$1.60^{+1.69+0.27}_{-0.57-0.27}$	$1.52^{+0.79+1.03}_{-0.67-0.86}$	$0.36^{+1.13+0.24}_{-0.11-0.24}$	$4.24^{+4.08+1.11}_{-1.22-0.96}$	7
9	5+	2+	1500+	750+	$0.28^{+1.41+0.09}_{-0.28-0.00}$	$0.16^{+1.13+0.11}_{-0.09-0.07}$	$0.42^{+0.55+0.13}_{-0.18-0.12}$	$0.01^{+0.24+0.03}_{-0.01--0.00}$	$0.88^{+2.61+0.18}_{-0.42-0.20}$	2
10	9+	3+	750+	750+	$0.00^{+0.72+0.00}_{-0.00-0.00}$	$0.01^{+0.65+0.01}_{-0.01-0.00}$	$0.00^{+0.33+0.00}_{-0.00-0.00}$	$0.00^{+0.68+0.00}_{-0.00-0.00}$	$0.01^{+1.57+0.00}_{-0.01-0.00}$	0
11	7+	1+	300+	300+	$126.54^{+10.12+13.34}_{-9.26-12.58}$	$146.71^{+6.60+8.98}_{-5.55-9.04}$	$85.54^{+9.13+14.77}_{-8.88-20.34}$	$26.34^{+2.98+11.74}_{-1.57-11.74}$	$385.14^{+19.28+27.23}_{-17.35-26.57}$	316
12	5+	1+	750+	750+	$2.82^{+2.36+0.73}_{-0.93-0.49}$	$3.26^{+2.13+0.77}_{-0.86-0.78}$	$9.01^{+1.95+1.67}_{-1.56-1.44}$	$0.82^{+1.45+0.66}_{-0.26-0.56}$	$15.90^{+5.11+2.01}_{-2.39-1.90}$	17

Jets + MET
CMS-SUS-15-003
JHEP 10 (2016) 006

Signal	Expected limit [fb] (full analysis)	Best aggregated region	Signal yield (best aggregated region)	Expected limit [fb] (best aggregated region)
$pp \to \tilde{g}\tilde{g}, \tilde{g} \to b\bar{b}\tilde{\chi}^0_1$ ($m_{\tilde{g}} = 1700\,GeV$, $m_{\tilde{\chi}^0_1} = 0\,GeV$)	4.80	2b very tight	3.19	9.83
$pp \to \tilde{g}\tilde{g}, \tilde{g} \to b\bar{b}\tilde{\chi}^0_1$ ($m_{\tilde{g}} = 1000\,GeV$, $m_{\tilde{\chi}^0_1} = 950\,GeV$)	393	2b tight	4.79	667
$pp \to \tilde{g}\tilde{g}, \tilde{g} \to q\bar{q}\tilde{\chi}^0_1$ ($m_{\tilde{g}} = 1600\,GeV$, $m_{\tilde{\chi}^0_1} = 0\,GeV$)	8.67	4j tight	5.31	17.2
$pp \to \tilde{g}\tilde{g}, \tilde{g} \to q\bar{q}\tilde{\chi}^0_1$ ($m_{\tilde{g}} = 1000\,GeV$, $m_{\tilde{\chi}^0_1} = 850\,GeV$)	357	7j tight	7.33	536
$pp \to \tilde{g}\tilde{g}, \tilde{g} \to t\bar{t}\tilde{\chi}^0_1$ ($m_{\tilde{g}} = 1500\,GeV$, $m_{\tilde{\chi}^0_1} = 0\,GeV$)	12.9	7j very tight	4.48	20.7
$pp \to \tilde{g}\tilde{g}, \tilde{g} \to t\bar{t}\tilde{\chi}^0_1$ ($m_{\tilde{g}} = 900\,GeV$, $m_{\tilde{\chi}^0_1} = 600\,GeV$)	555	3b tight	5.55	1100
$pp \to \tilde{t}\bar{\tilde{t}}, \tilde{t} \to t\tilde{\chi}^0_1$ ($m_{\tilde{t}} = 750\,GeV$, $m_{\tilde{\chi}^0_1} = 0\,GeV$)	41.8	2b tight	5.79	73.7
$pp \to \tilde{t}\bar{\tilde{t}}, \tilde{t} \to t\tilde{\chi}^0_1$ ($m_{\tilde{t}} = 600\,GeV$, $m_{\tilde{\chi}^0_1} = 250\,GeV$)	151	2b medium	17.5	321
$pp \to \tilde{t}\bar{\tilde{t}}, \tilde{t} \to t\tilde{\chi}^0_1$ ($m_{\tilde{t}} = 250\,GeV$, $m_{\tilde{\chi}^0_1} = 150\,GeV$)	18600	2b medium	9.37	73900
$pp \to \tilde{b}\bar{\tilde{b}}, \tilde{b} \to b\tilde{\chi}^0_1$ ($m_{\tilde{b}} = 800\,GeV$, $m_{\tilde{\chi}^0_1} = 0\,GeV$)	26.9	2b tight	5.83	48.1
$pp \to \tilde{b}\bar{\tilde{b}}, \tilde{b} \to b\tilde{\chi}^0_1$ ($m_{\tilde{b}} = 500\,GeV$, $m_{\tilde{\chi}^0_1} = 350\,GeV$)	451	2b medium	21.3	777
$pp \to \tilde{q}\bar{\tilde{q}}, \tilde{q} \to q\tilde{\chi}^0_1, \tilde{q}_L + \tilde{q}_R(\tilde{u}, \tilde{d}, \tilde{s}, \tilde{c})$ ($m_{\tilde{q}} = 1200\,GeV$, $m_{\tilde{\chi}^0_1} = 0\,GeV$)	14.0	2j tight	7.85	18.3
$pp \to \tilde{q}\bar{\tilde{q}}, \tilde{q} \to q\tilde{\chi}^0_1, \tilde{q}_L + \tilde{q}_R(\tilde{u}, \tilde{d}, \tilde{s}, \tilde{c})$ ($m_{\tilde{q}} = 600\,GeV$, $m_{\tilde{\chi}^0_1} = 0\,GeV$)	148	4j medium	300	267
$pp \to \tilde{q}\bar{\tilde{q}}, \tilde{q} \to q\tilde{\chi}^0_1, \tilde{q}_L + \tilde{q}_R(\tilde{u}, \tilde{d}, \tilde{s}, \tilde{c})$ ($m_{\tilde{q}} = 700\,GeV$, $m_{\tilde{\chi}^0_1} = 500\,GeV$)	493	4j medium	34.0	902

Sensitivity from best aggregated region typically factor 2 worse than full analysis.

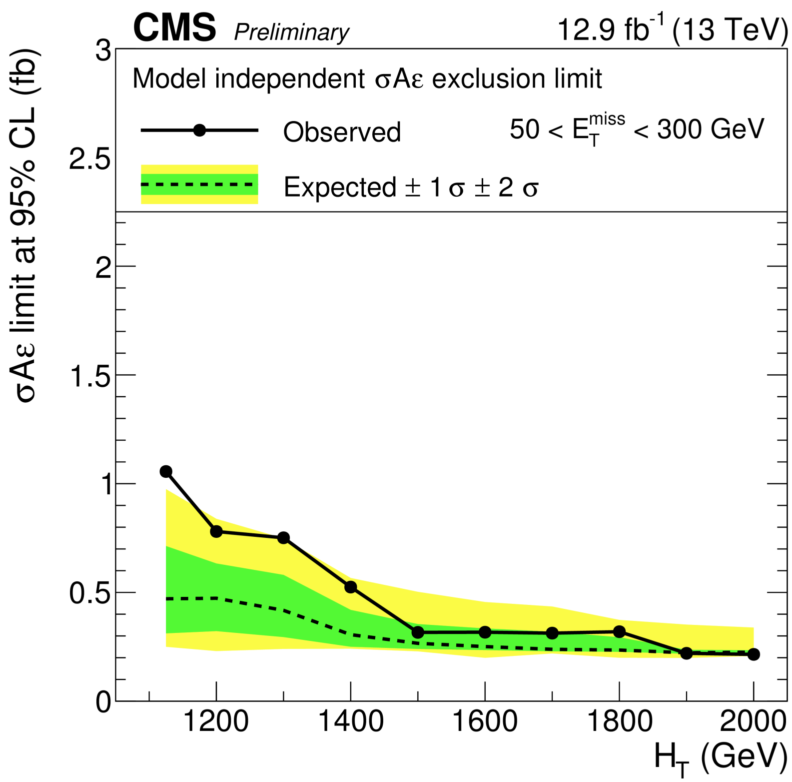
Much easier to use.

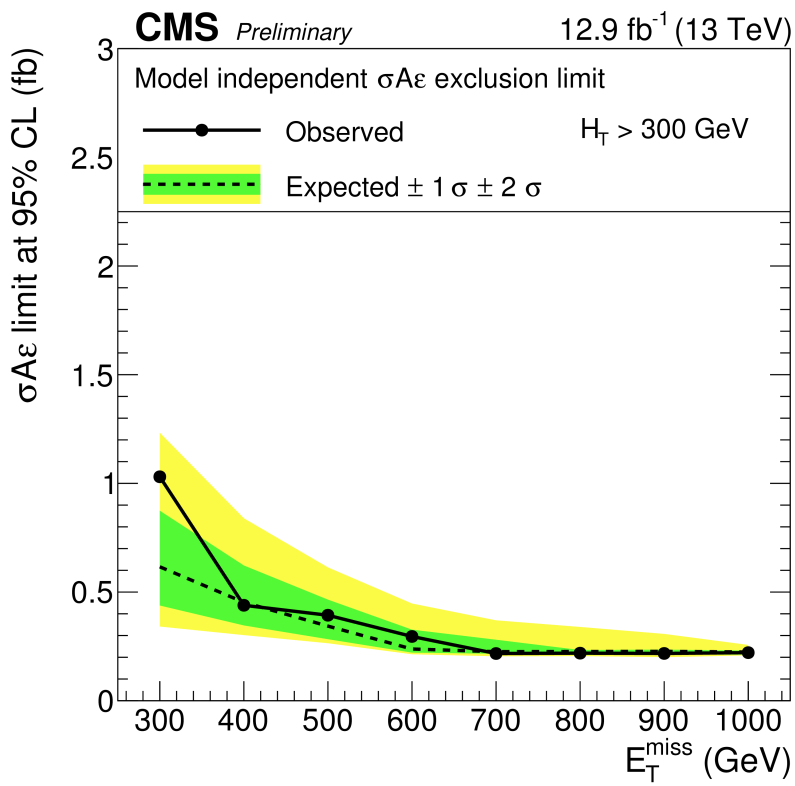
Aggregated regions or equivalent will be provided for all CMS SUSY searches unless it is technically not possible

Solution 2

- Provide background covariance matrix for full set of exclusive regions
  - If too many to be practical, merge nearby regions to get to a smaller number
- Better sensitivity than single inclusive aggregated regions, recover ~ full sensitivity of analysis
- More statistical manipulations needed by reinterpreters
  - Can use set of exclusive regions with proper BG correlation
  - Or define custom single signal region with correct BG uncertainty (easier, but generally less sensitive)
- Under discussion. See talk on "*Recasting searches using a simplified likelihood approach*" later today.

Another possibility: model independent limits





Same-sign dileptons
CMS-SUS-PAS-16-020

Conclusions

- Importance of providing information for reinterpretations is recognized by CMS SUSY
- Improvements wrt past practices are in the works
- Keeping things simple for the analysis teams is an important requirement