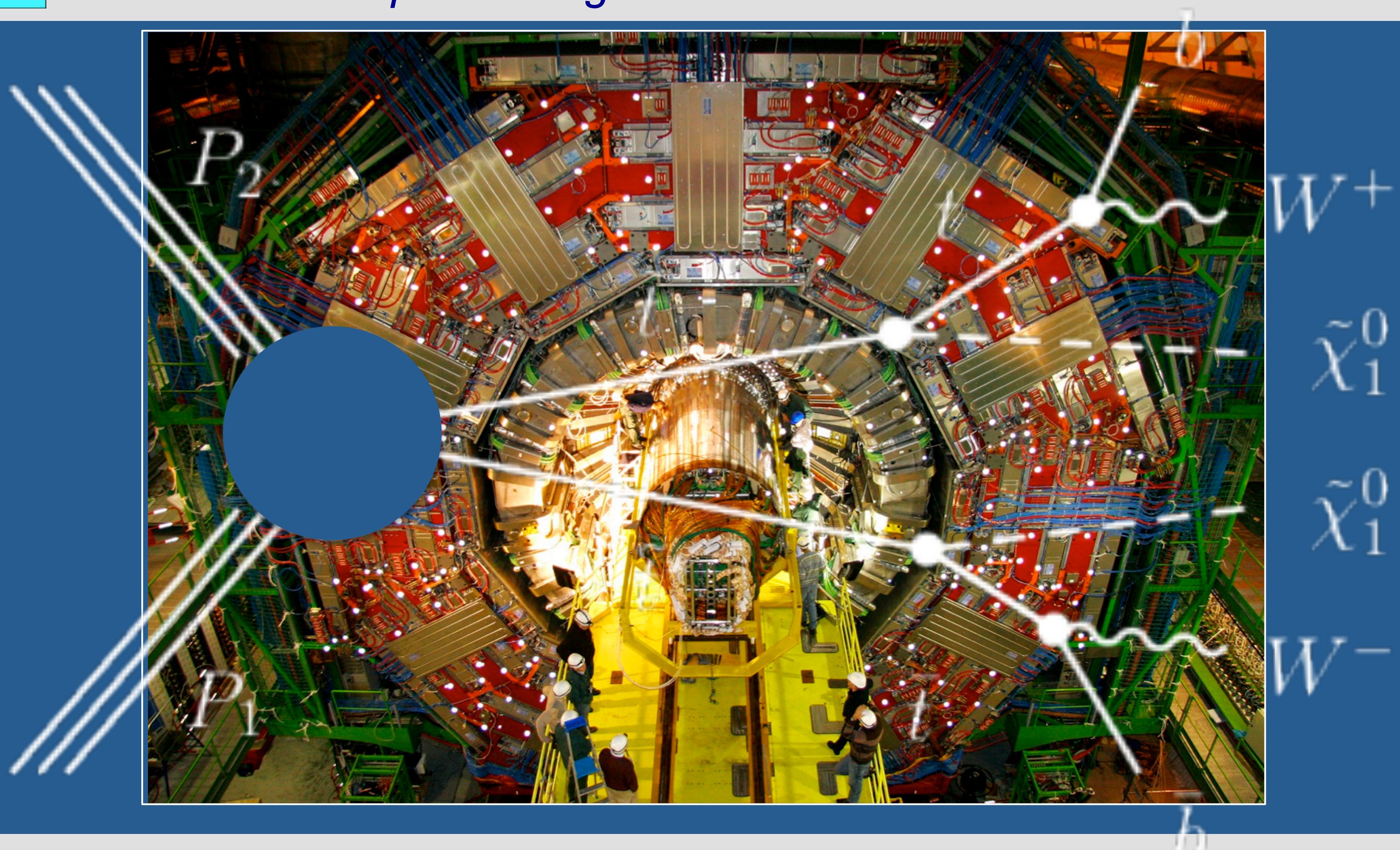
Searches for Supersymmetry in the CMS Experiment

Jeffrey D. Richman (UC Santa Barbara)
Representing the CMS Collaboration



21st International Conference on Supersymmetry and Unification of Fundamental Interactions
International Center for Theoretical Physics, Trieste, August 26–31, 2013

Outline

- Big themes and challenges for SUSY searches
- Inclusive (generic) searches
- Naturalness-inspired searches:
  $\tilde{t}\,,\,\tilde{b},\,\tilde{g}$
- Search for EWKinos & sleptons
  $\tilde{\chi}_i^0\,,\,\tilde{\chi}_j^{\pm}\;,\tilde{\ell}$
- SUSY decays with Higgs
- Multi-lepton & R-parity violating signatures
- Conclusions

Drawing courtesy Sergio Cittolin

CMS PUBLIC SUSY RESULTS
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

New results in all of these areas. Most use 19.5 fb^{-1} ($\sqrt{s}$ =8 TeV).

CMS SUSY talks in the parallel sessions (I)

1. Search for SUSY in hadronic final states at CMS (Mon.)

   Joshua THOMPSON

2. Search for SUSY in the single and di-lepton final state at CMS (Mon.)

   Marco-Andrea BUCHMANN

3. Search for SUSY in multilepton final states at CMS (Mon.)

   Andrea GOZZELINO

4. Search for SUSY in final states with photons at CMS (Tues.)

   David MORSE

5. Interpretation of CMS SUSY results and outlook to 14 TeV data taking (Tues.)

   Frank GOLF

6. Dark matter searches in monojet and monophoton events at CMS (Tues.)

   Tai SAKUMA

CMS SUSY talks in the parallel sessions (II)

7. Search for direct stop and sbottom production at CMS (Thurs.)

   Mariarosaria D'ALFONSO

8. Search for EWK production of gauginos and sleptons at CMS (Thurs.)

   Ben HOOBERMAN

9. Interpretations of CMS SUSY searches in the context of R-parity violation (Fri.)

   Matthew WALKER

My talk: just a small sampling of the many CMS SUSY results.

OTHER CMS PLENARY SESSION TALKS

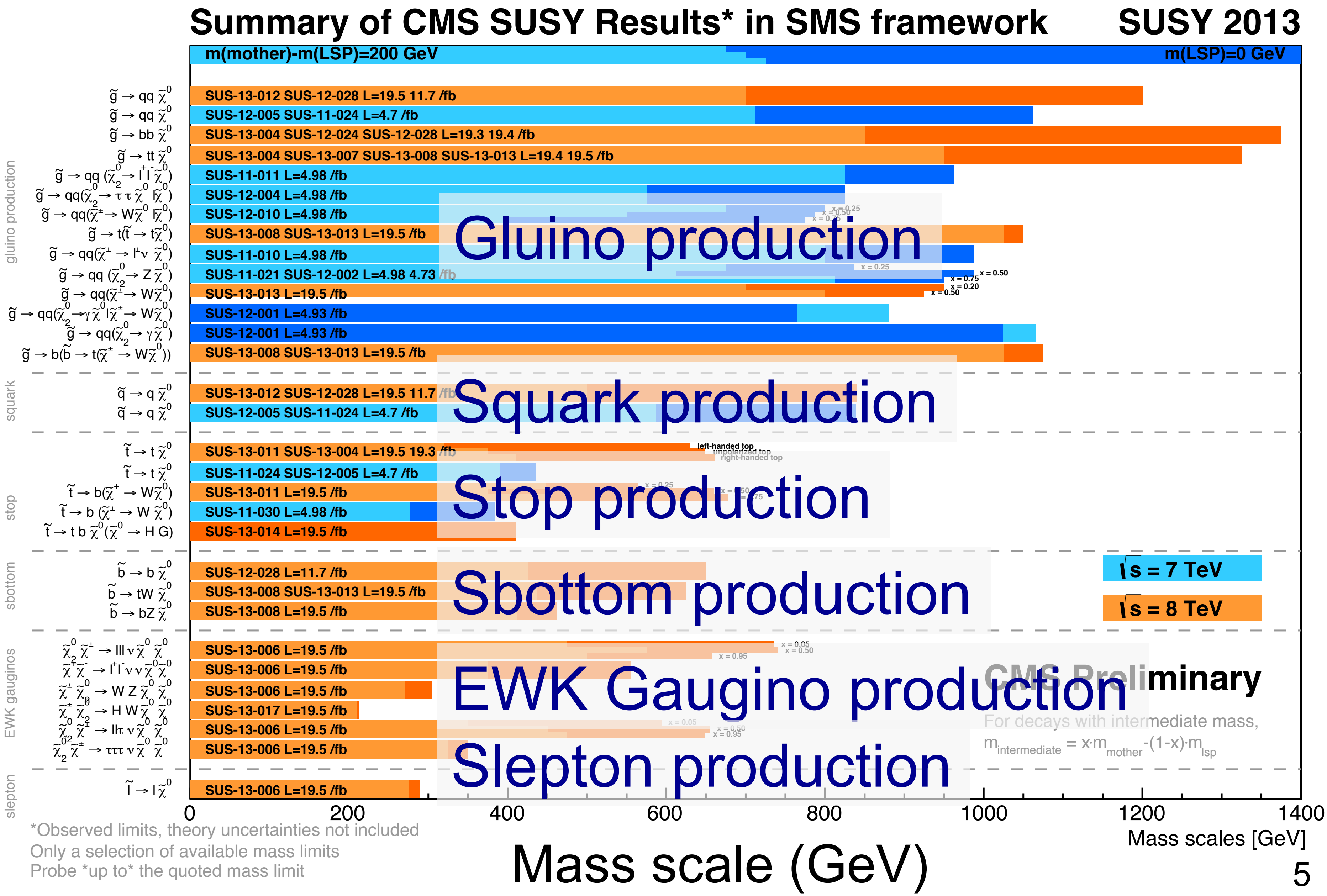
Recent results on Higgs physics from CMS *(Tues.)*

Sridhara DASU

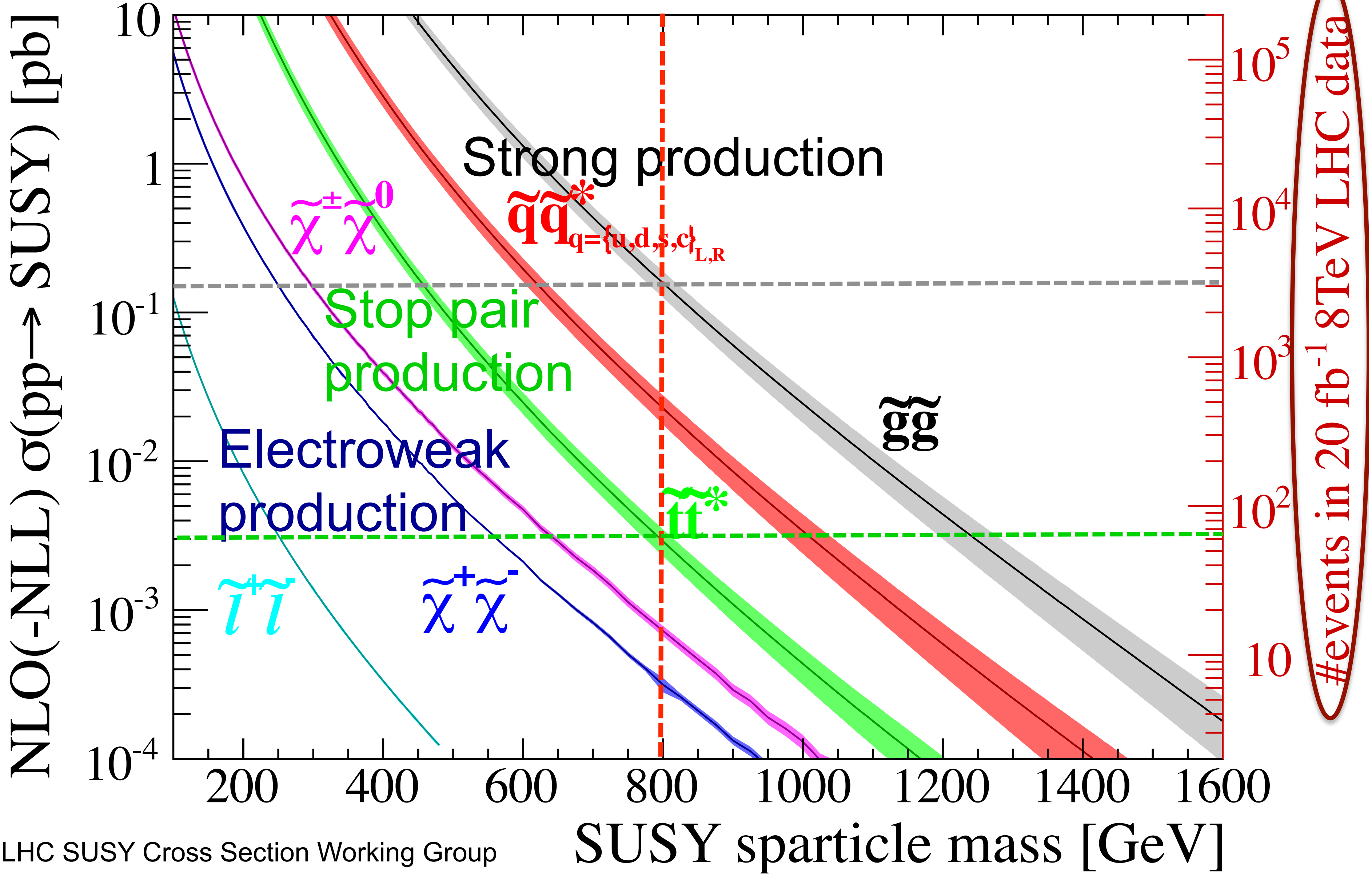
Recent results from exotic searches from CMS *(Fri.)*

Sunil SOMALWAR

CMS SUSY overview: a broad program



Big themes: production and decays



LHC SUSY Cross Section Working Group

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/SUSYCrossSections

arXiv:1206.2892

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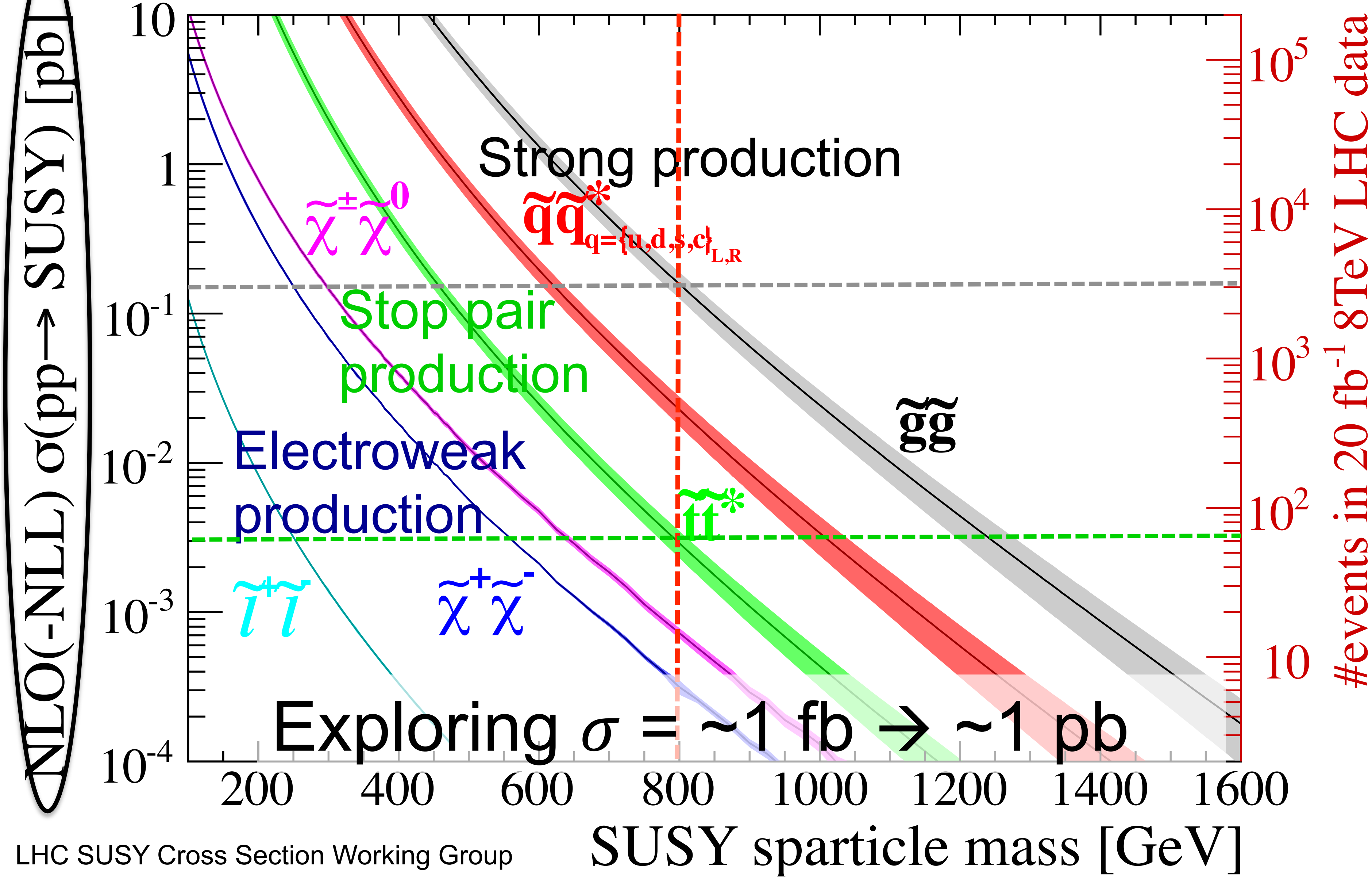

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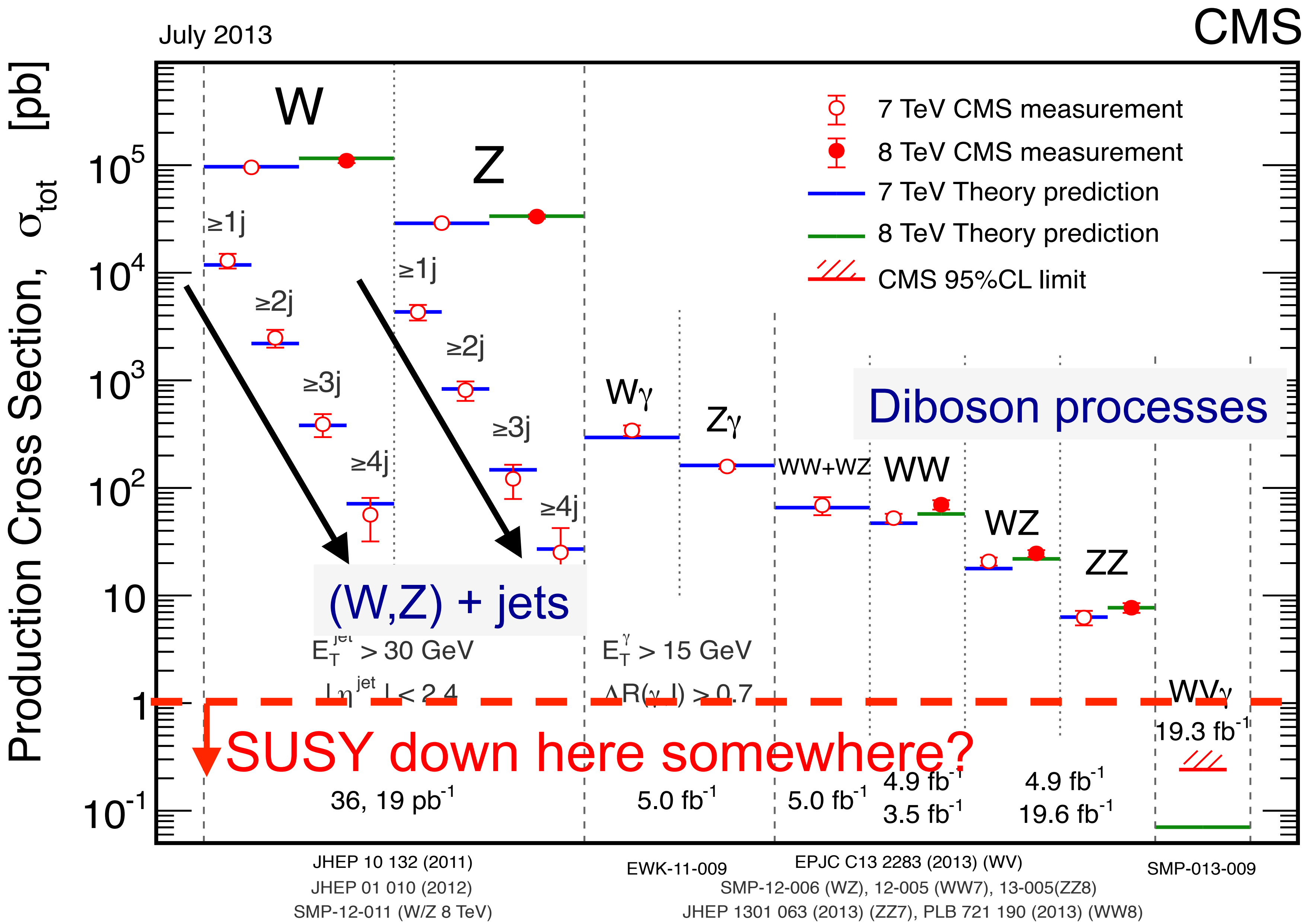
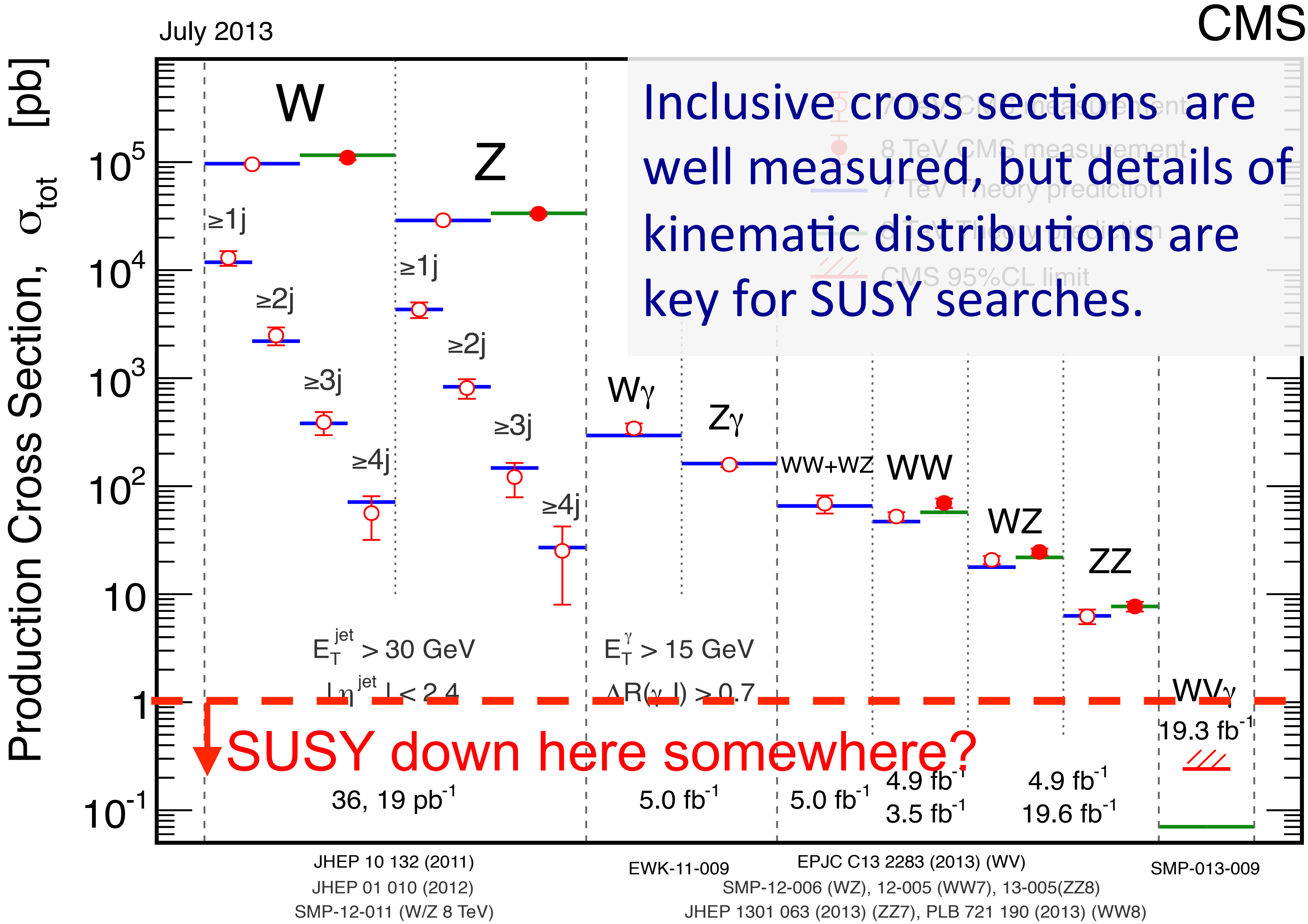
Big themes: background measurement



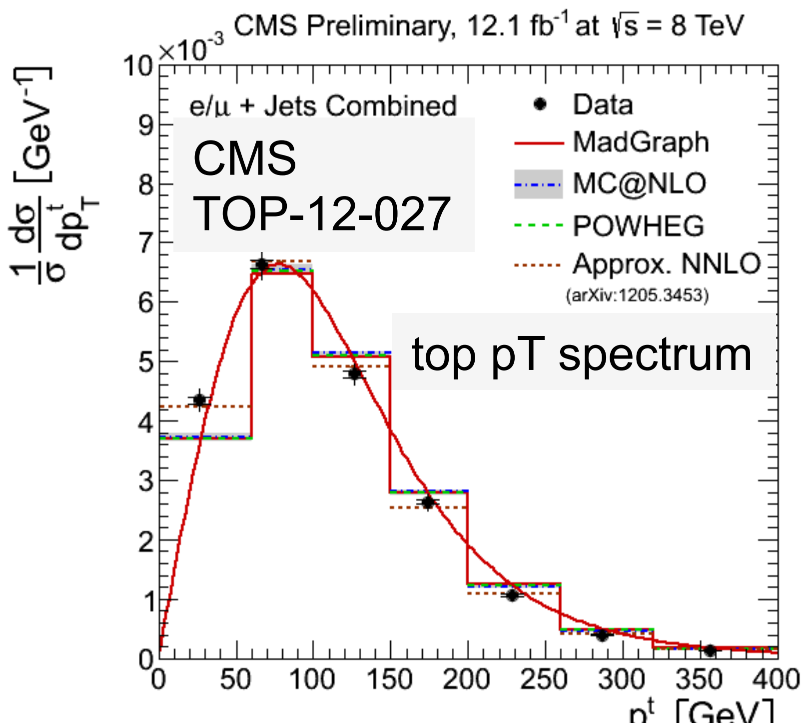
Big themes: background measurement



Inclusive cross sections are well measured, but details of kinematic distributions are key for SUSY searches.

Big themes: $pp \to t\bar{t}$ key SUSY background

- Heaviest SM particle $\sigma(pp \to t\bar{t}) = (227 \pm 3 \pm 11 \pm 10)$ pb at 8 TeV
  https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsTOPSummaryPlots
- Jets, b-jets, leptons, missing transverse momentum (MET)
- Now have many detailed studies of kinematic distributions.



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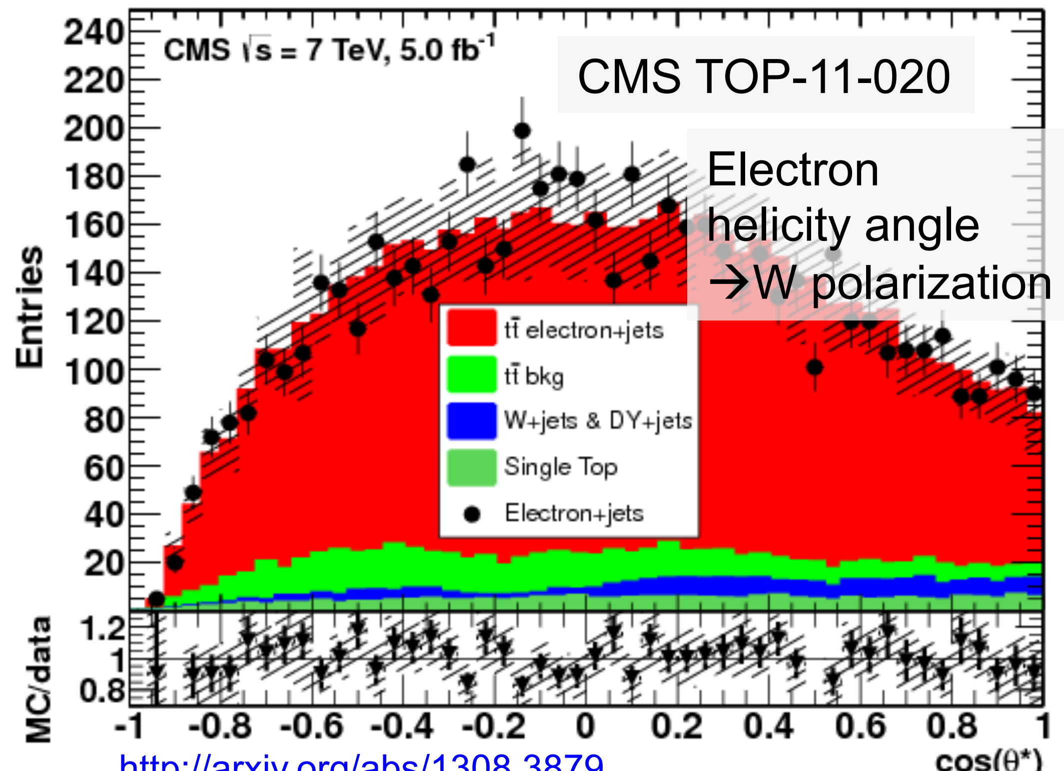
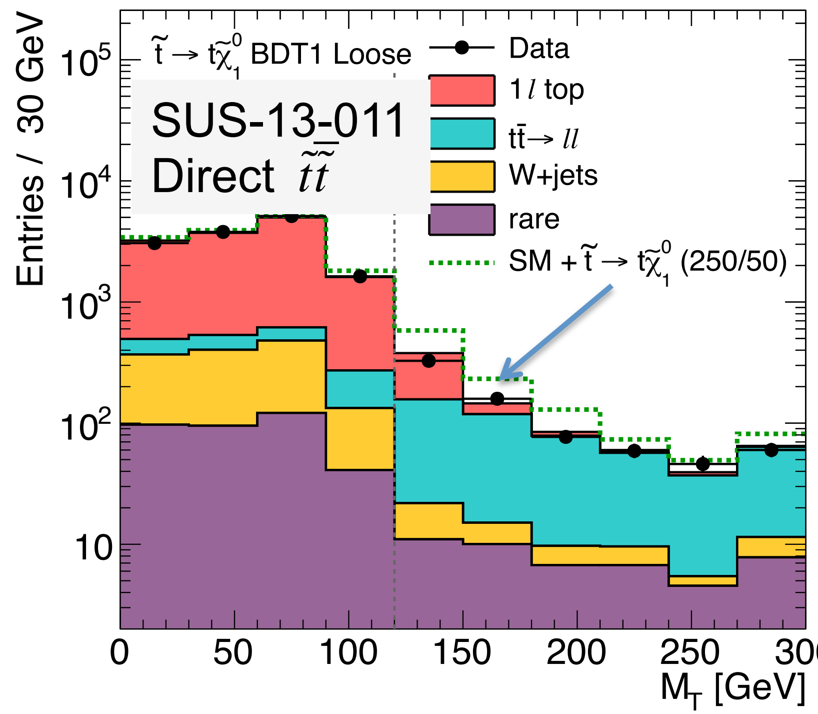


http://arxiv.org/abs/1308.3879

Big themes: tails of SM kinematic distributions

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS13011

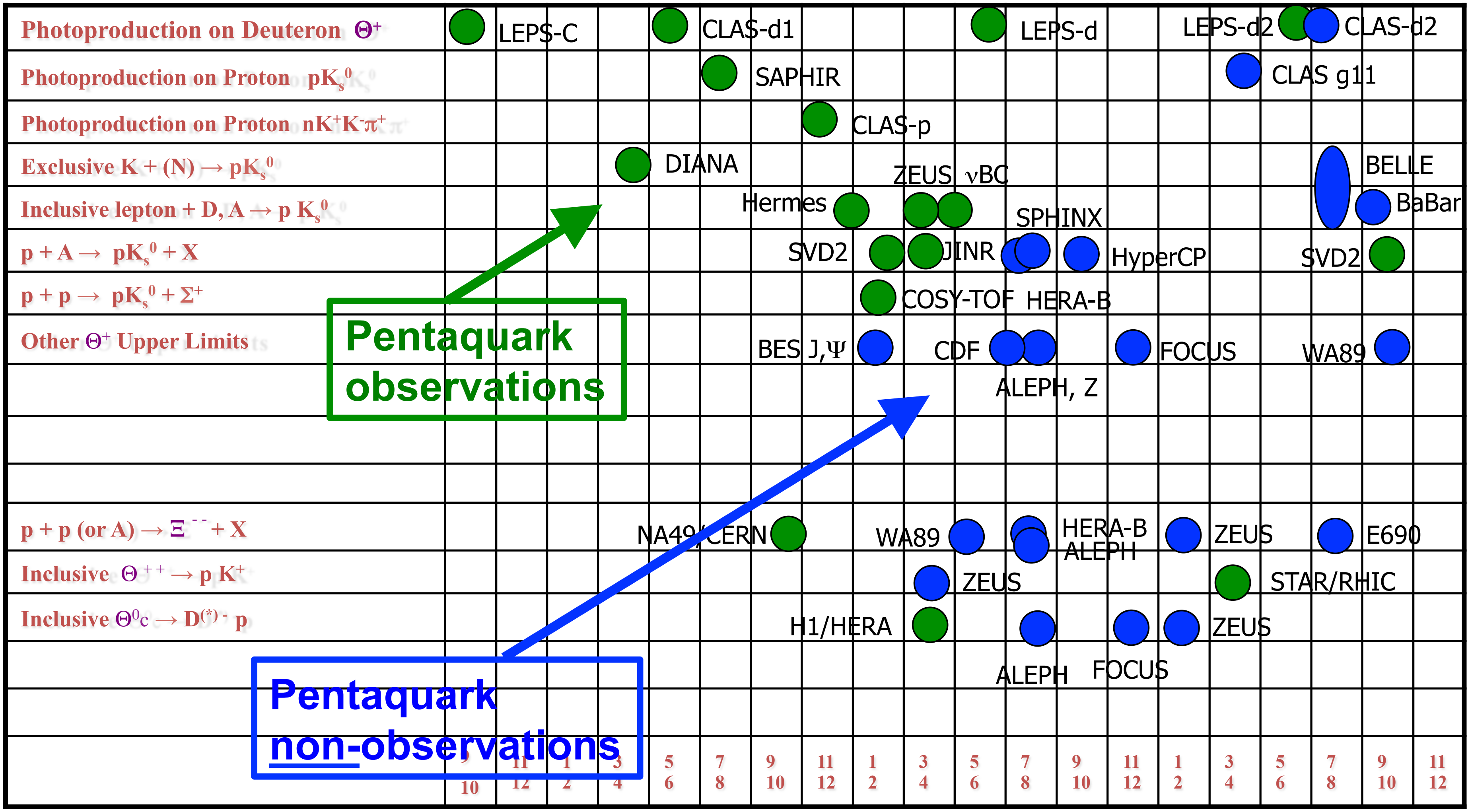
- SUSY processes usually do not have narrow features in observed distributions.
- Search is performed in the *extreme tails* of SM processes. Narrow kinematic region of phase space; possible rare detector effects also.



- As far as possible, use data-driven methods based on control samples → use *multiple, complementary approaches.* MC/theory plays key role in validating our understanding of these control samples.
- Multiple methods: critical for discovery scenarios!

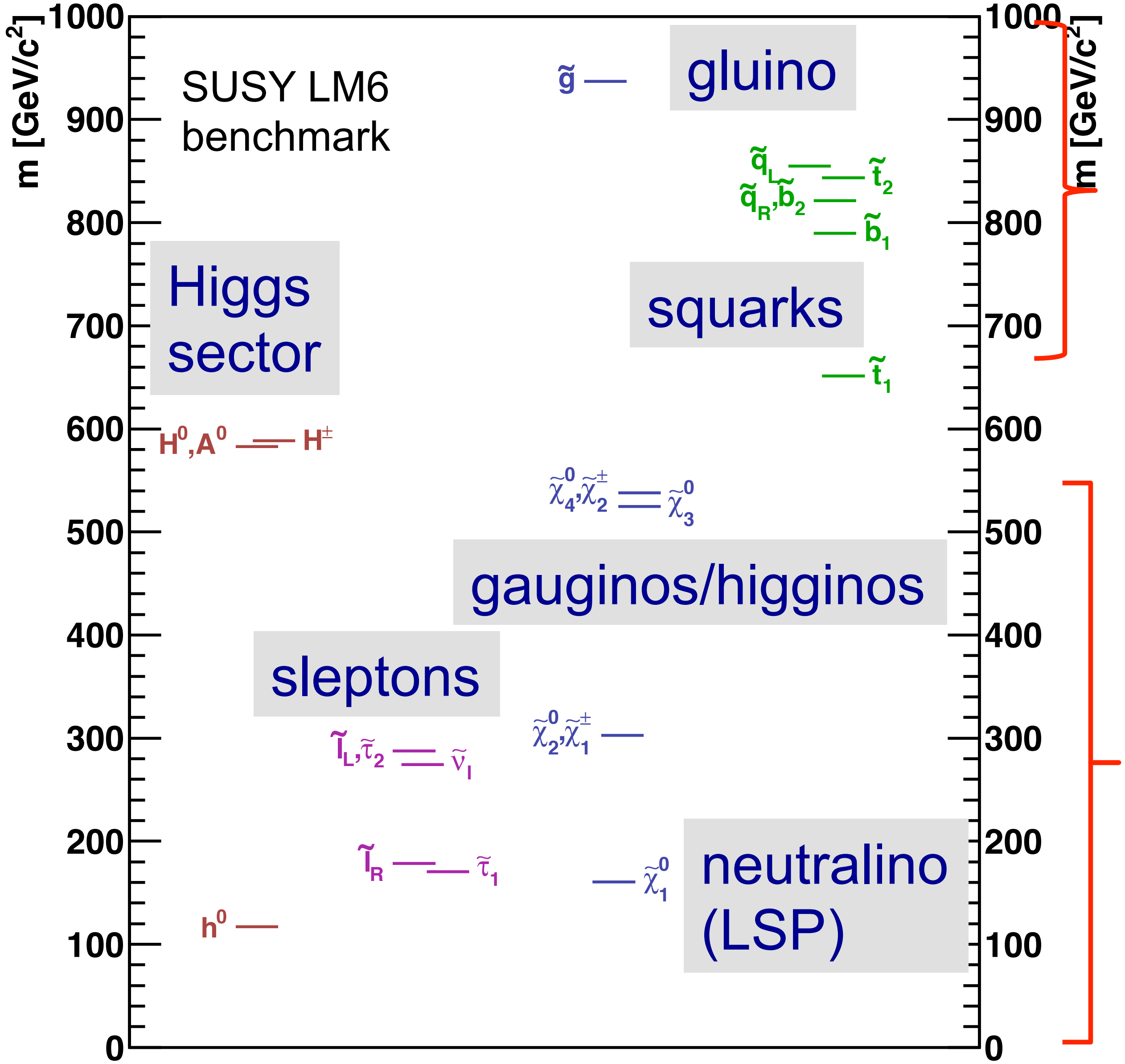
The pentaquark phenomenon, 2002-2005

Slide courtesy of R. Schumacher From *Particles and Nuclei International Conference*, Santa Fe, 2005



Let's not do this! (I don't think we will.)

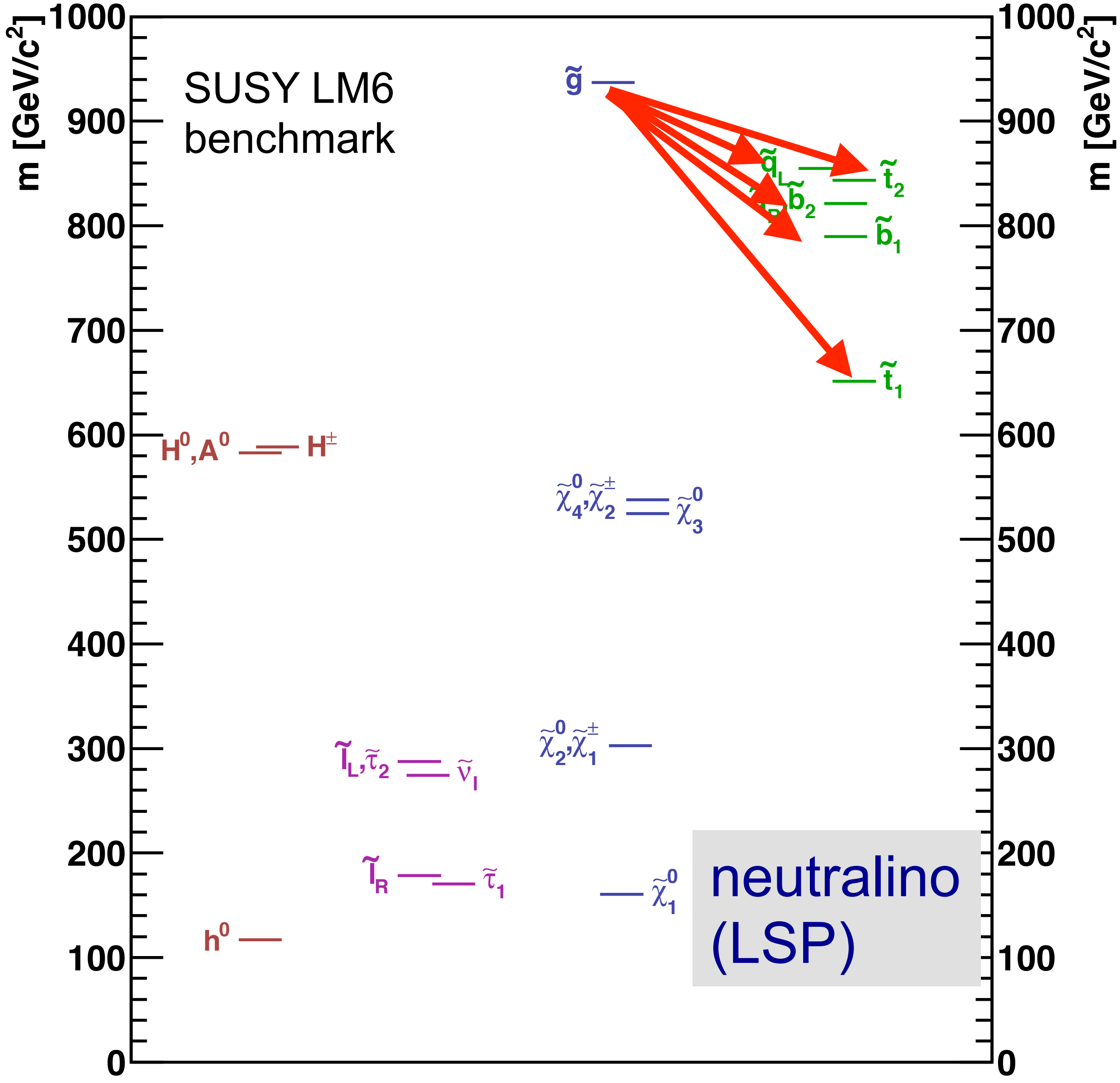
Big themes: many (& complex) signatures



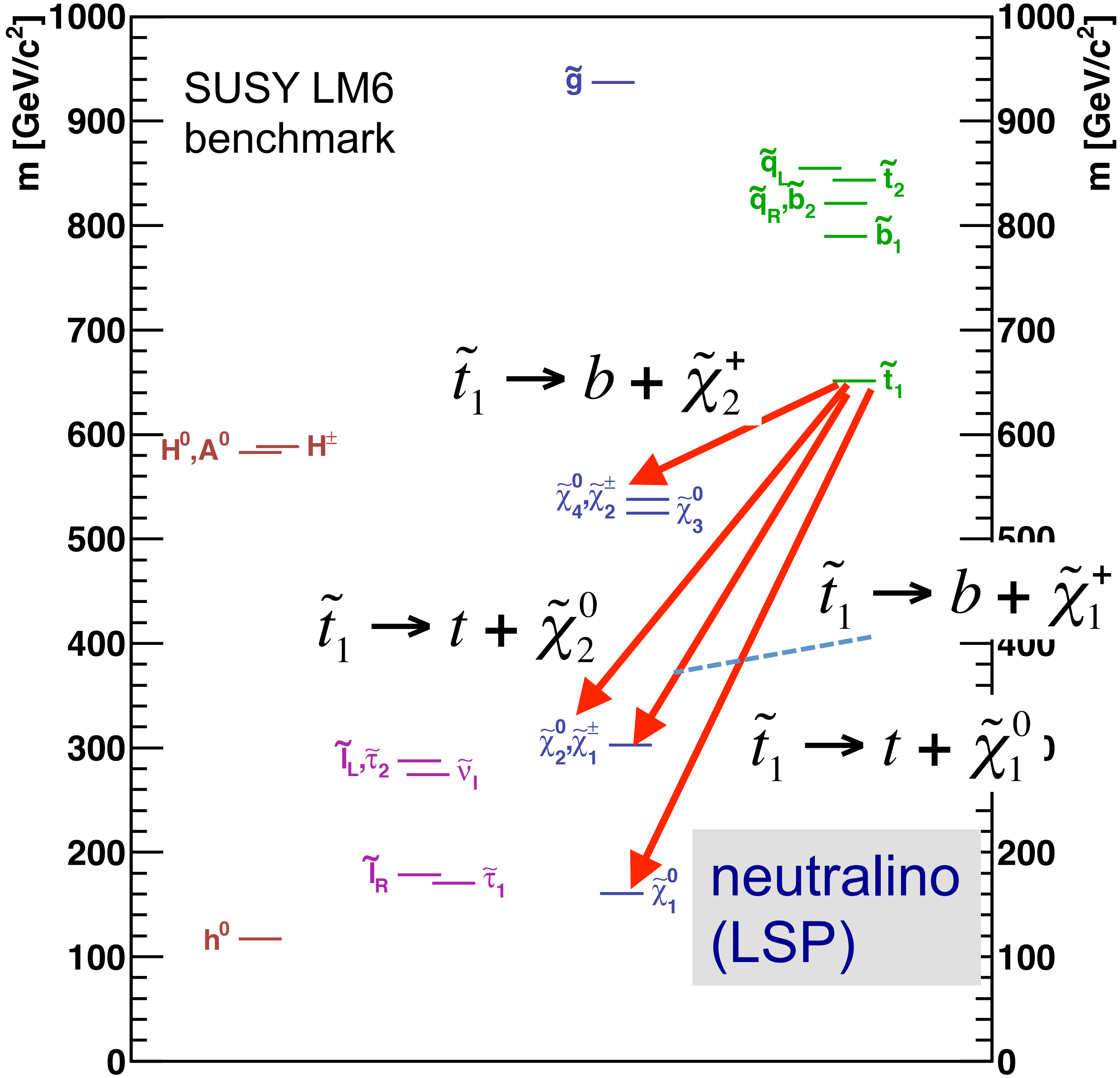
Direct production via strong processes

Direct production via electroweak processes

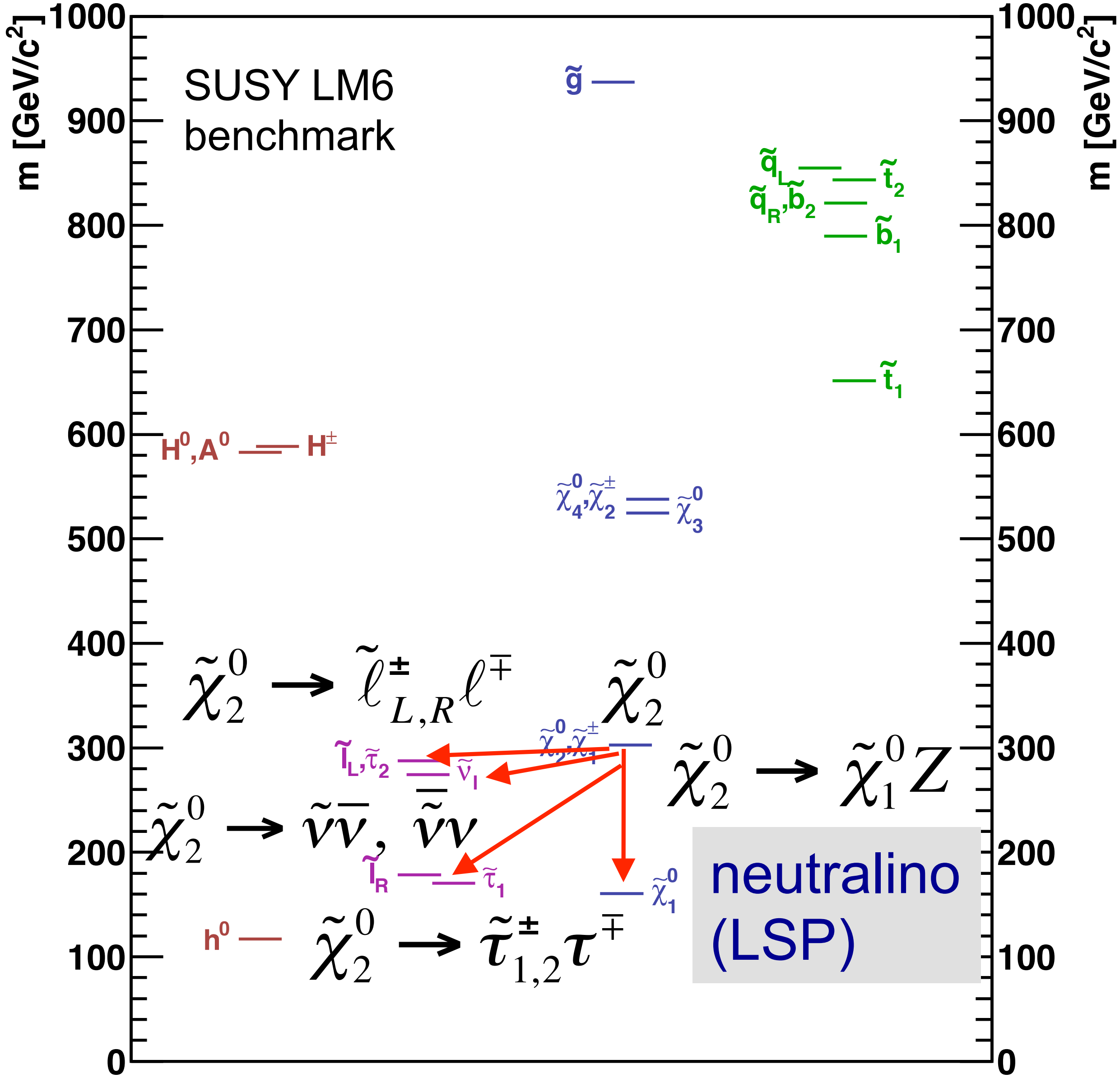
SUSY cascade starting from gluino decay



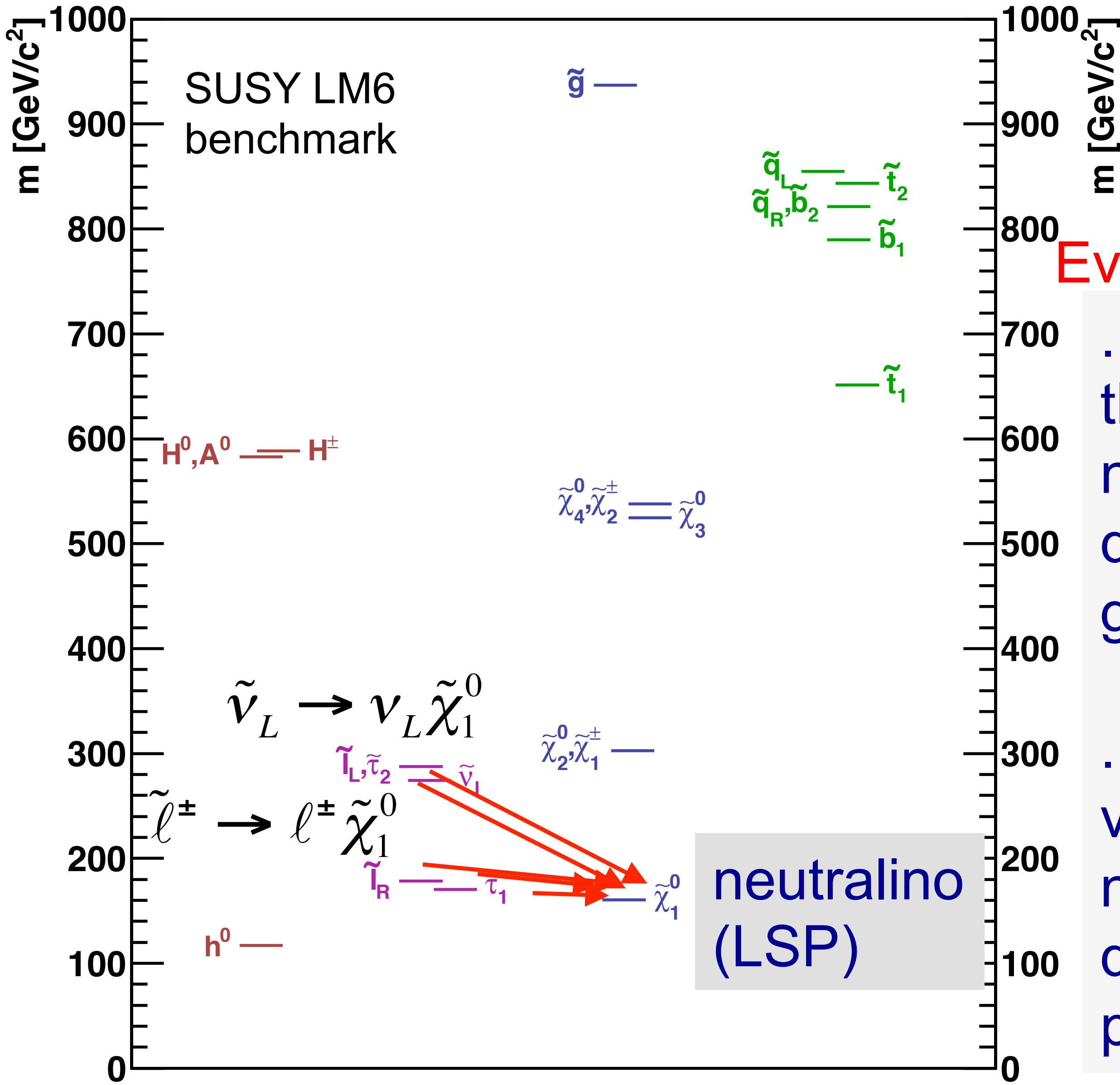
Decays of ~t_1 → neutralinos, charginos



Decays of $\tilde{\chi}_2^0$: here come the leptons!



Decays of $\tilde{\ell}^{\pm}_{L,R}$, $\tilde{\tau}^{\pm}_{1,2}$, $\tilde{\nu}_L$: more leptons!

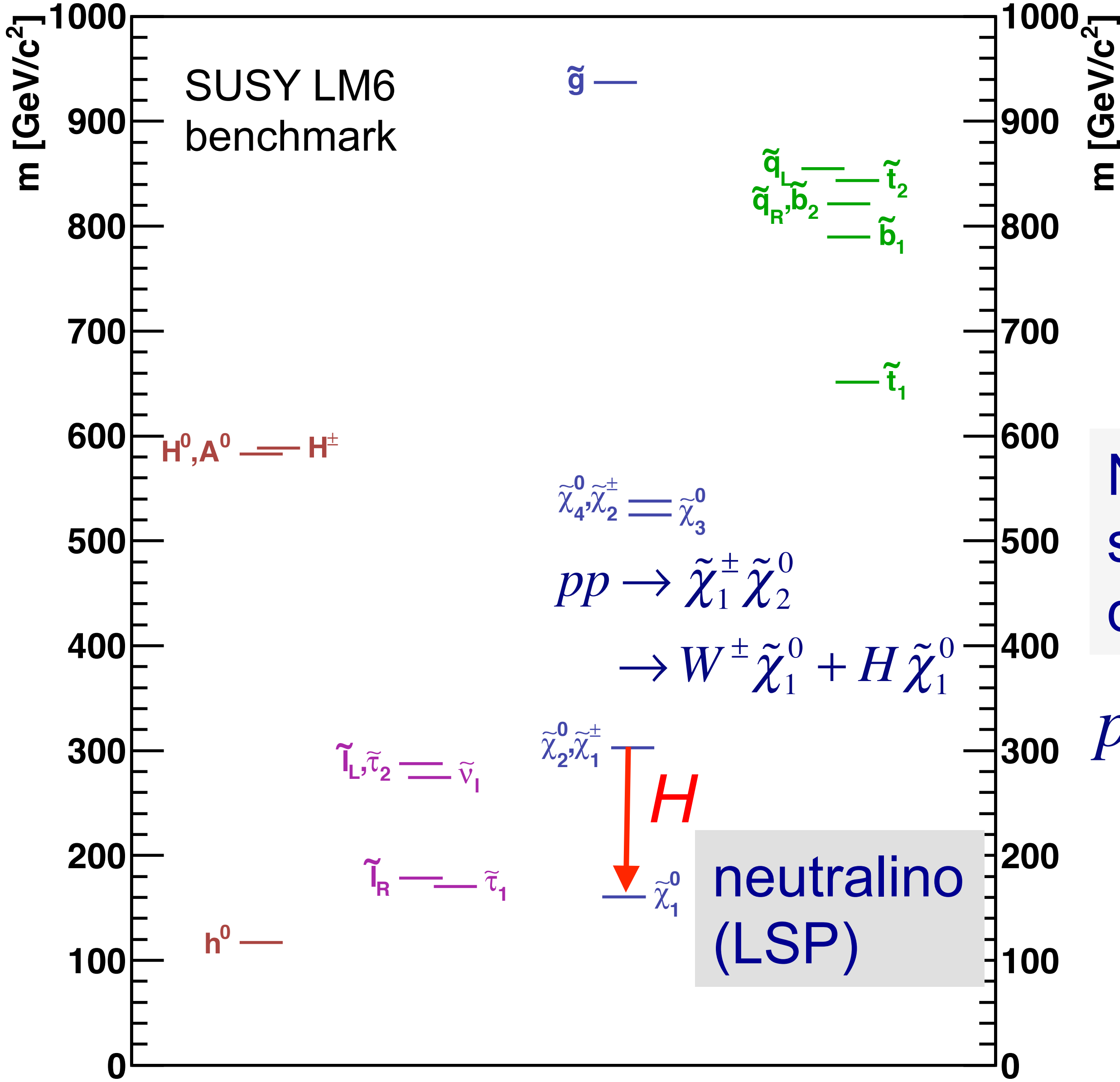


Even more possibilities

...and in GMSB, the lightest neutralino can decay into a gravitino → MET

... and in R-parity violating SUSY, the neutralino can decay into SM particles →no MET

Decays of $\tilde{\ell}^{\pm}_{L,R}$, $\tilde{\tau}^{\pm}_{1,2}$, $\tilde{\nu}_L$: more leptons!



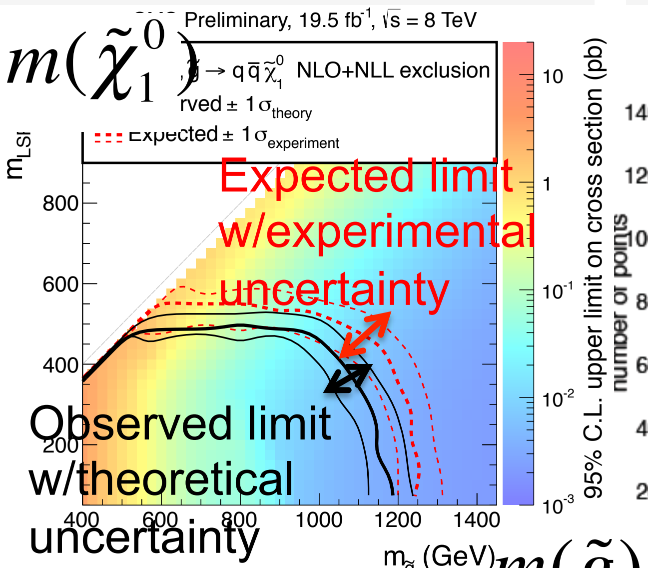
New program of searches for SUSY decays with Higgs.

$$pp \to \tilde{\chi}^{\pm}_1 + \tilde{\chi}^0_2$$
$$\to W^{\pm} \tilde{\chi}^0_1 + H \tilde{\chi}^0_1$$

Big themes: Interpretation(s)

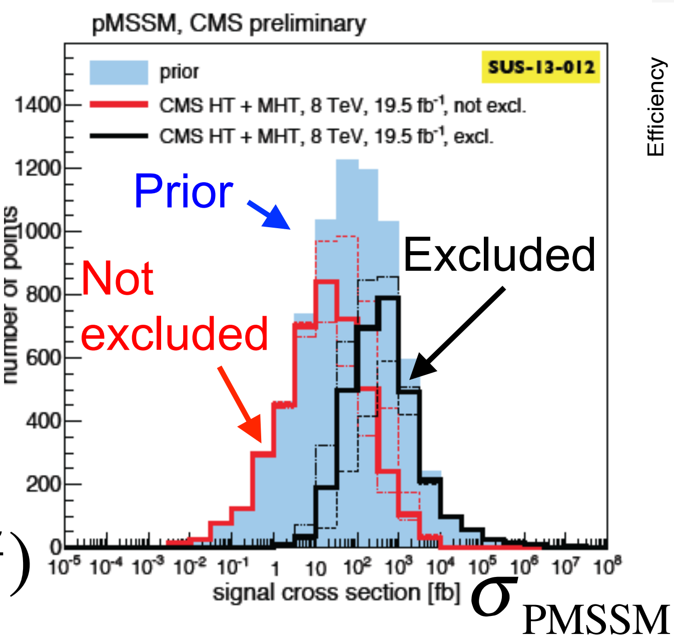
- Early LHC running: heavy use of cMSSM to connect with results from Tevatron. (Not sufficiently general.)
- Today: Extensive use of simplified models. Reasonably well suited to natural SUSY spectra. Big assumption: BF=100%.
- Alternatives: pMSSM and efficiency models.

SMS: $\tilde{g}\tilde{g},\, \tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$
SUS-13-012 (Jets+MHT)

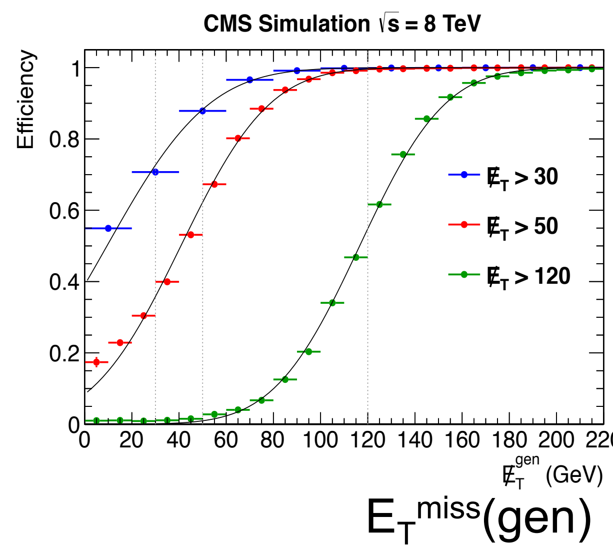


https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS13012

pMSSM interpretation of SUS-13-012



Efficiency model for SUS-13-013 $(\ell^{\pm}\ell^{\pm})$



https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS13013

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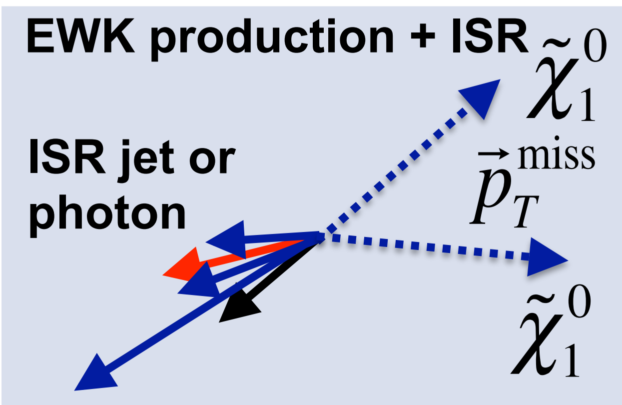
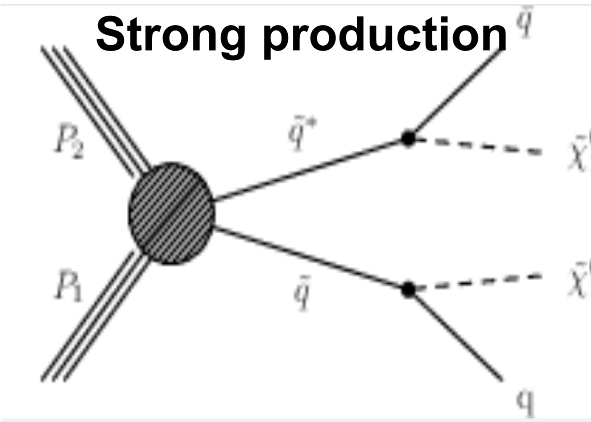
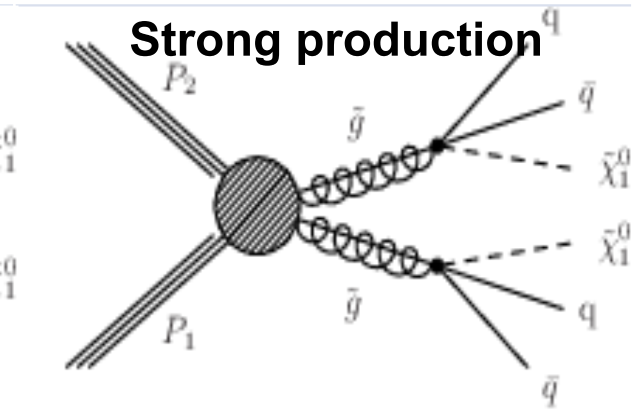
Drawing courtesy Sergio Cittolin

CMS PUBLIC SUSY RESULTS
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

New results in all of these areas. Analyses use 19.5 fb^{-1} ($\sqrt{s}$ =8 TeV).

Generic searches for jets + MET

1 Jet + MET Dark matter search	2 Jets + MET $e.g.,\ \ pp \to \tilde{q}\bar{\tilde{q}}$	Multi. Jets + MET $e.g.,\ \ pp \to \tilde{g}\tilde{g}$
		
SM: Z(νν) + 1 jet	SM: QCD dijets + fake MET from mismeasurement of jets; W + jets,...	SM: many sources! Both real & fake MET.

For dark matter results, see **Sunil Somalwar** plenary & **Tai Sakuma** parallel talk.

All-hadronic SUSY search using α_T

SUS-12-028 http://arxiv.org/abs/1303.2985

J. Thompson & F. Golf parallel talks

$$\alpha_T \equiv E_T^{J_2} / M_T(J_1 J_2) = \frac{\sqrt{E_T^{J_2} / E_T^{J_1}}}{\sqrt{2(1-\cos\Delta\varphi_{J_1 J_2})}}$$

Randall and Tucker-Smith
http://arxiv.org/pdf/0806.1049

QCD J_2 J_1

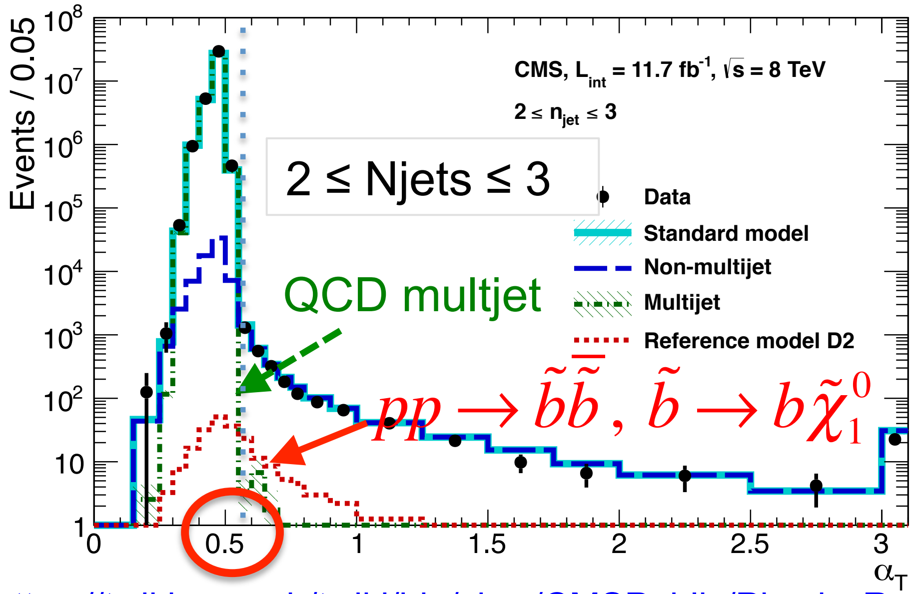
$$\alpha_T \approx \frac{\sqrt{E_T^{J_2} / E_T^{J_1}}}{2} \leq \frac{1}{2}$$

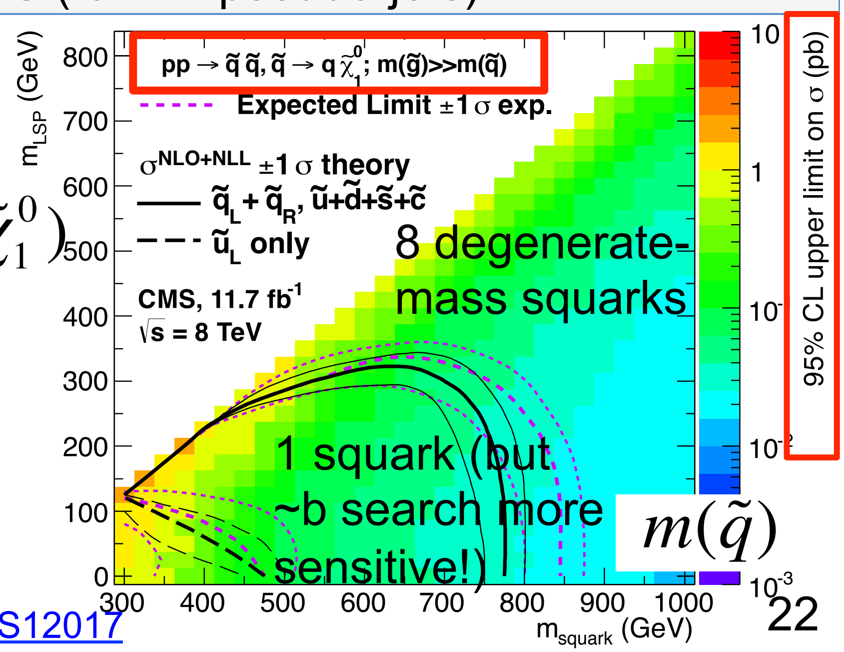
SUSY $\tilde{q}\bar{\tilde{q}} \rightarrow (q\tilde{\chi}_1^0)(\bar{q}\tilde{\chi}_1^0)$ → dijets + MET

J_2 J_1

$$\alpha_T \approx \frac{\sqrt{E_T^{J_2} / E_T^{J_1}}}{\Delta\varphi_{J_1 J_2}}$$

Generalized to multijet events in CMS (form 2 pseudo-jets).





https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS12017

Generic hadronic SUSY search using MHT

SUS-13-012 https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS13012 **J. Thompson** parallel talk

- Signature: Jets + MHT; events with leptons are vetoed
  - Jets: ≥3 jets with $p_T > 50$ GeV, no b-tagging.
  - Veto event if MHT vector is ≈aligned with any of 3 leading jets.
- Bin data in
  - HT
  - missing HT (MHT)
  - Jet multiplicity (3—5, 6—7, ≥8 jets)

$$H_T = \sum_{j=jets} \left|\vec{p}_T^{\,j}\right|$$

$$\not{H}_T = \left|\vec{\not{H}}_T\right| = \left|-\sum_{j=jets} \vec{p}_T^{\,j}\right|$$

- Background estimation: largely data driven.

• ttbar with W→$l\,\nu$
• W → $l\,\nu$ + jets
• ttbar with W→τ (→h) ν
• W → τ (→h) ν + jets

Control sample: Single-lepton + jets + MHT

• Z→$\nu\nu$ + jets

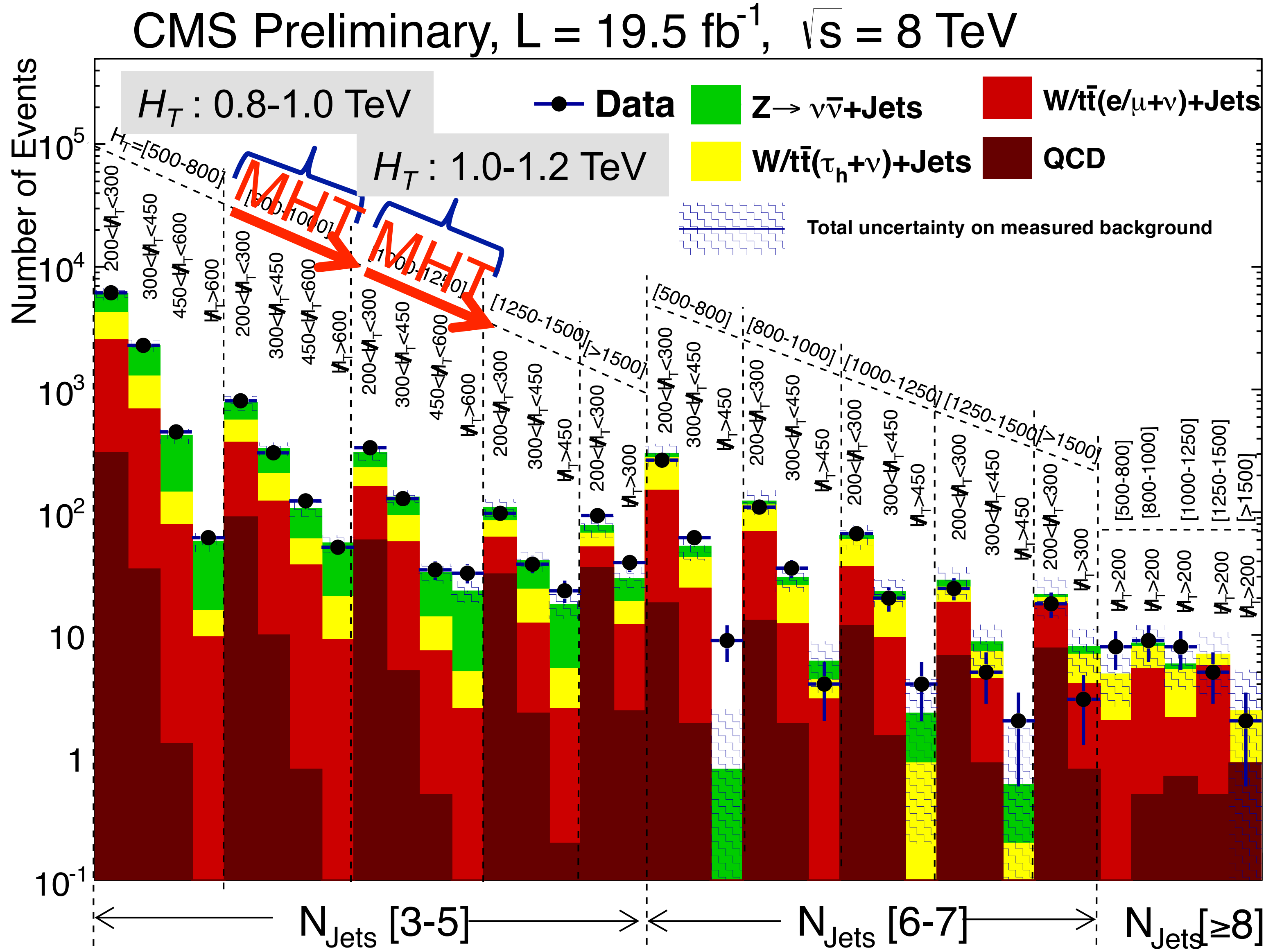
Control samples:
γ + jets,
Z($\mu\mu$)+jets

• QCD multijet events
MHT ~ aligned with high pT jet.

Control sample:
Multijets with re-balance and smear procedure

Distribution in bins of N(jets), H_T, and $\not{H}_T$

CMS PAS SUS-13-012



Statistical interlude

- Consider the bin with
  - N(observed) = 9 events
  - N(background) = 0.8 ± 1.7 events

See CMS PAS SUS-13-012, Table 1, p. 10

Njets: 6-7
HT: 500-800 GeV
MHT>450 GeV

- First, let's ignore the uncertainty on the background. What is the probability for a Poisson with μ=0.8 to fluctuate to at least 9 events?
  - Prob($n \geq 9 \mid \mu = 0.8$) = 1.8×10^{-7}

  Have we discovered new physics?

- NO! The uncertainty is crucial!
  - Prob($n \geq 9 \mid \mu = 0.8 \pm 1.7$) $\approx$ 0.15

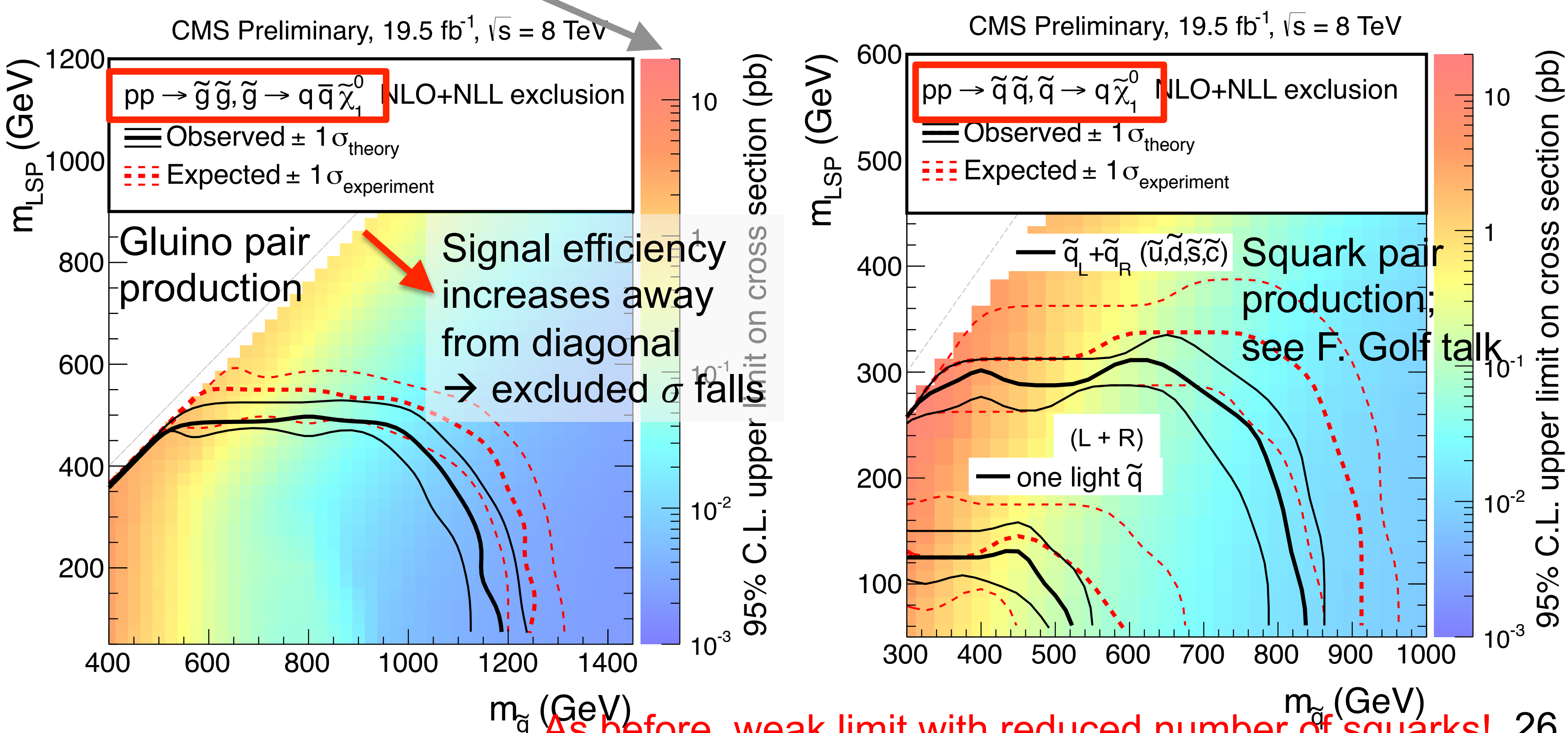
- This example highlights the importance of <u>quantifying the uncertainties on the SM backgrounds.</u>

Search for generic jets and MET: results

- Simplified model exclusion plots

CMS PAS SUS-13-012

1. Compute excluded cross section for each model in param space
2. Compare to reference cross section to see if model excluded
   - Assume 100% branching fraction for stated process!



As before, weak limit with reduced number of squarks!

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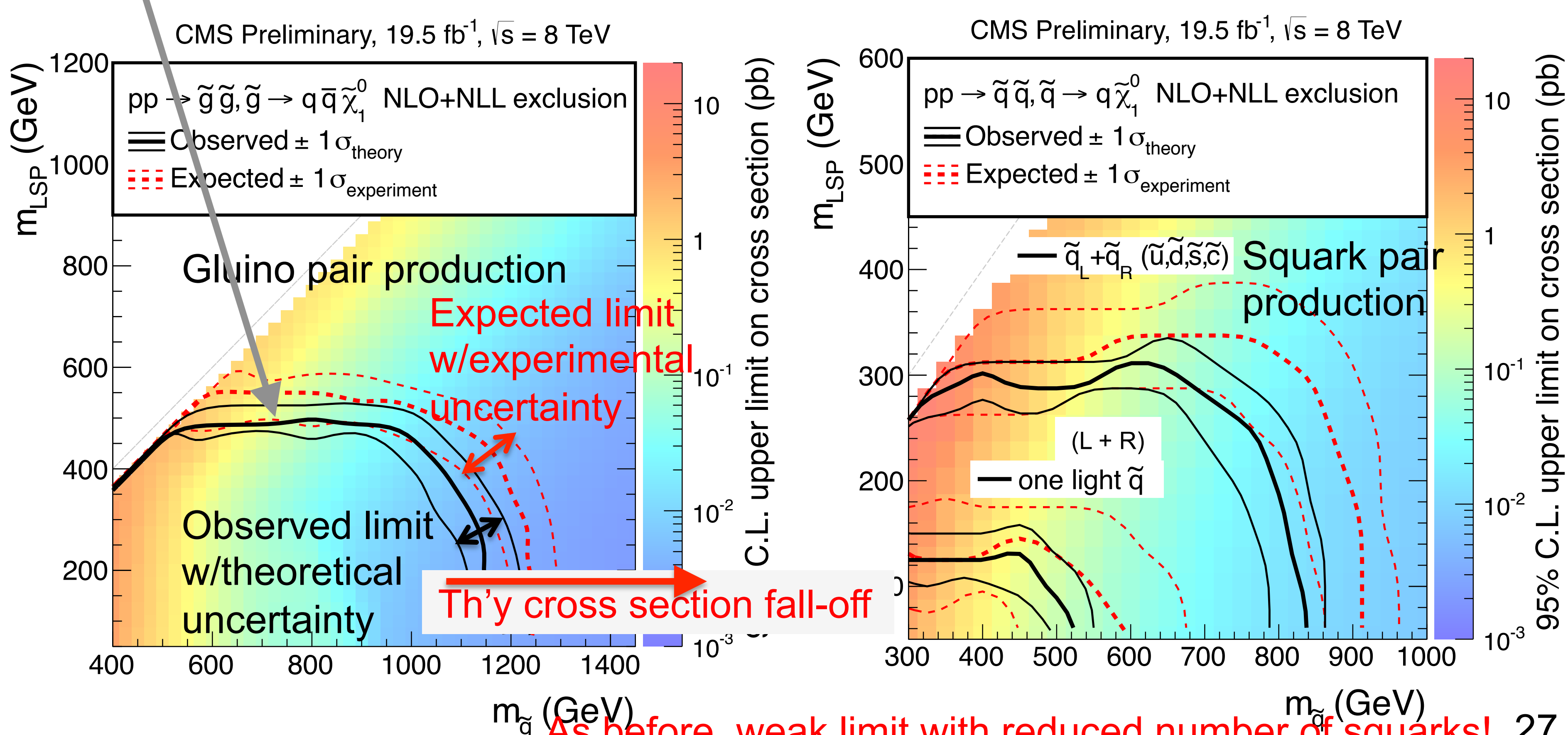

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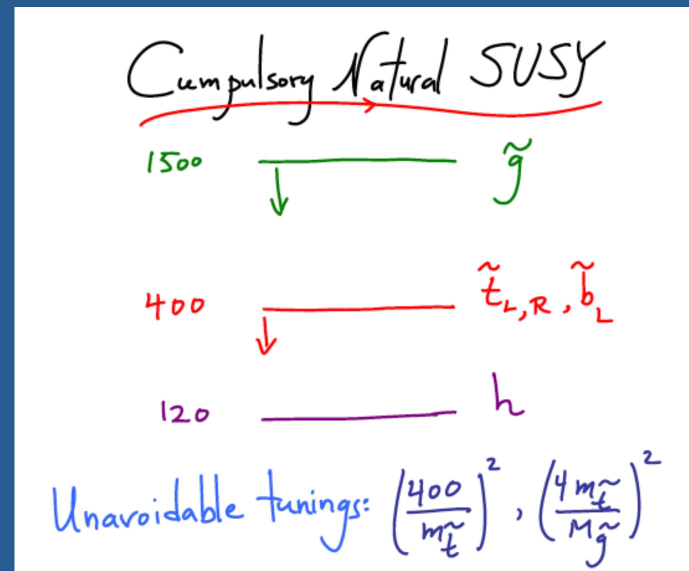
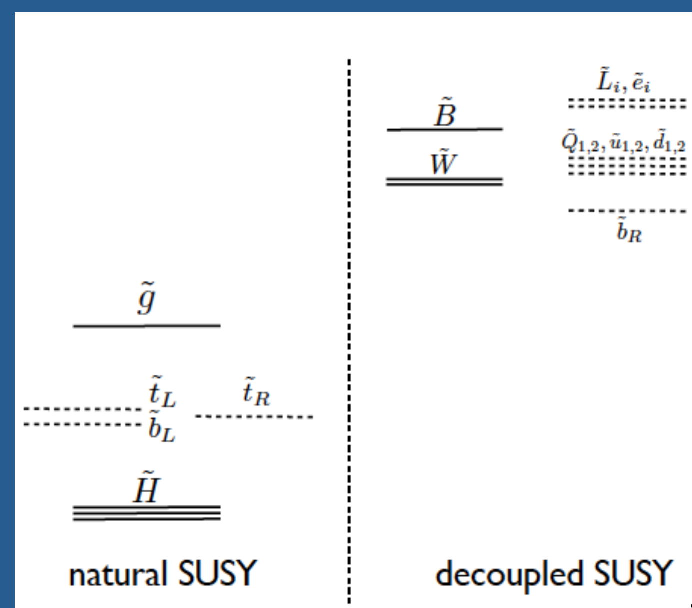
The focus on natural SUSY signatures

- With the discovery of the/a Higgs boson, the problem of the stability of $m(H)$ against radiative corrections has become urgent.
- Many searches designed for signatures motivated by a “natural SUSY” solution to the gauge hierarchy problem.

N. Arkani-Hamed, http://indico.cern.ch/getFile.py/access?contribId=7&sessionId=2&resId=0&materialId=slides&confId=157244

M. Papucci, J.T. Ruderman, and A. Weiler, *Natural SUSY Endures*, http://arxiv.org/abs/1110.6926

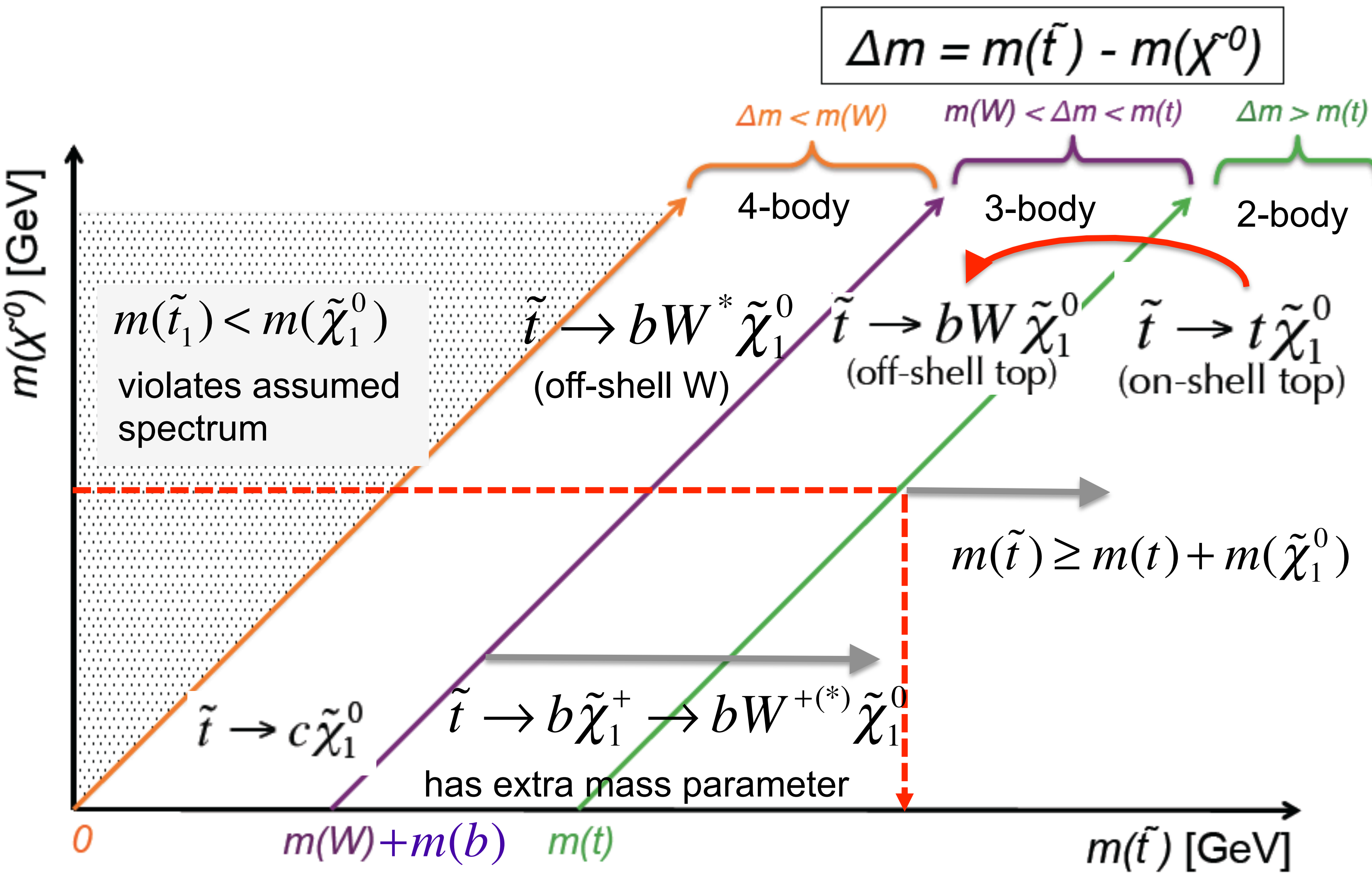




Search for direct stop production: $pp \to \tilde{t}_1 \bar{\tilde{t}}_1$

SUS-13-011 **Parallel talks: Mariarosaria D'Alfonso, Frank Golf**

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS13011 http://arxiv.org/abs/1308.1586



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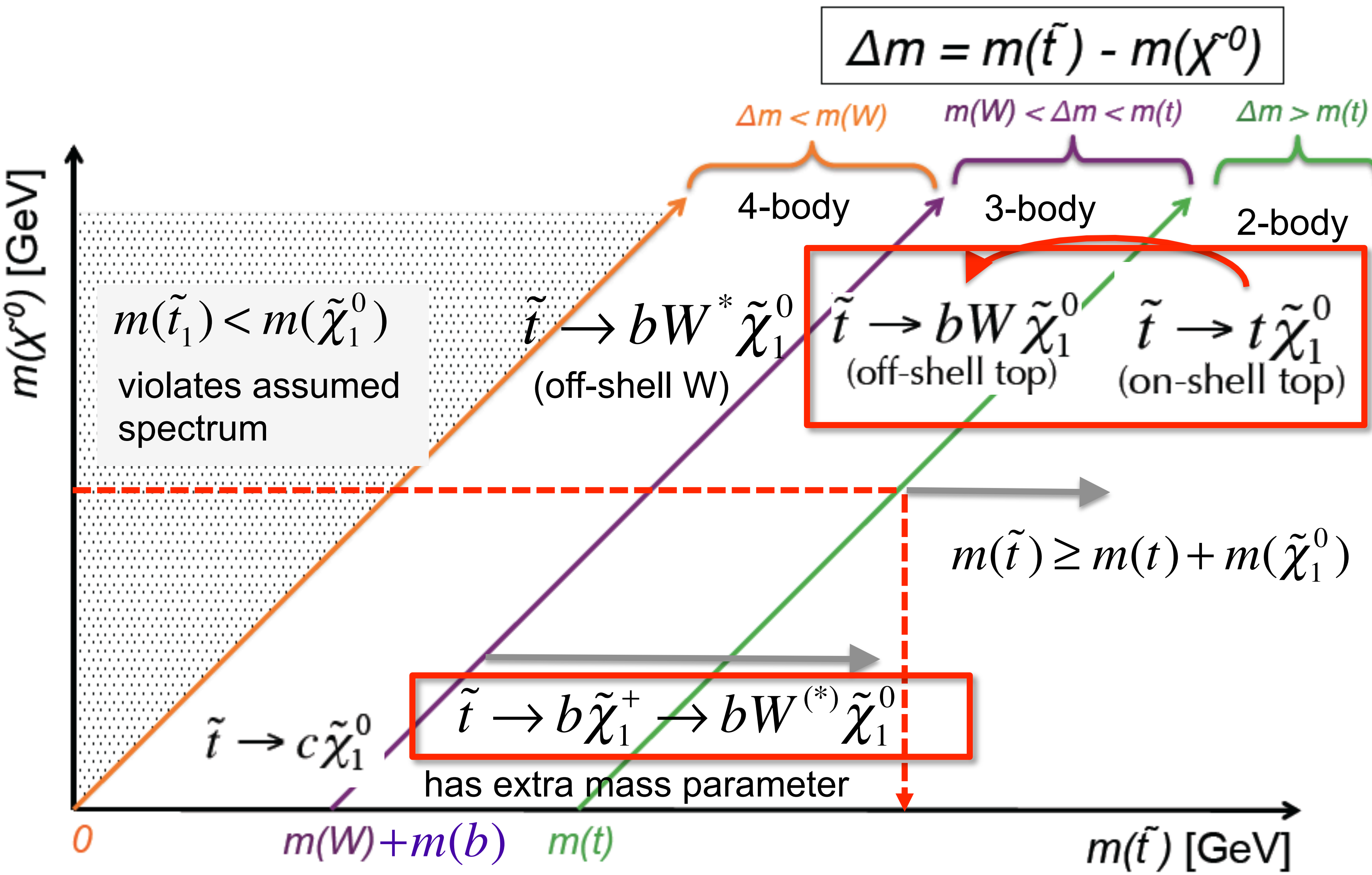

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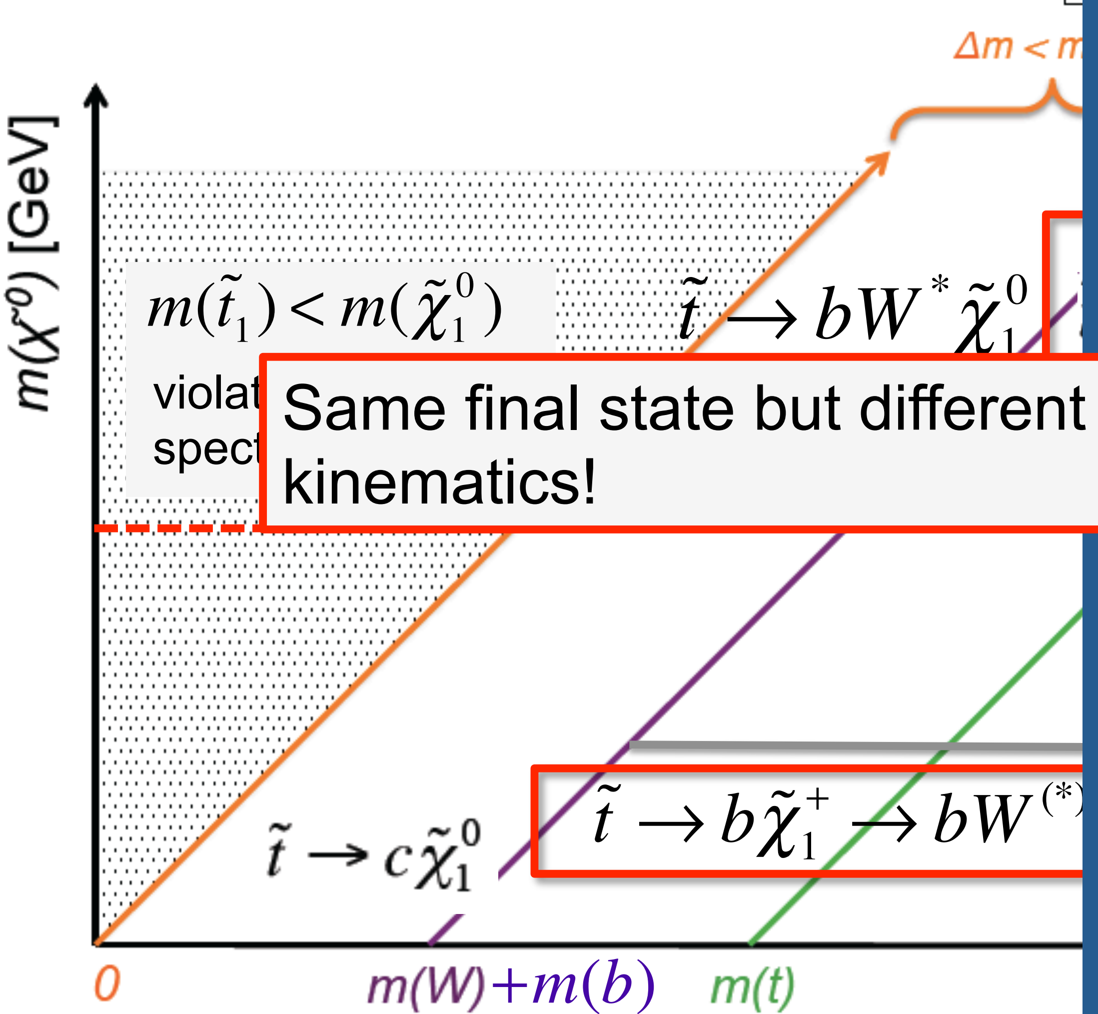
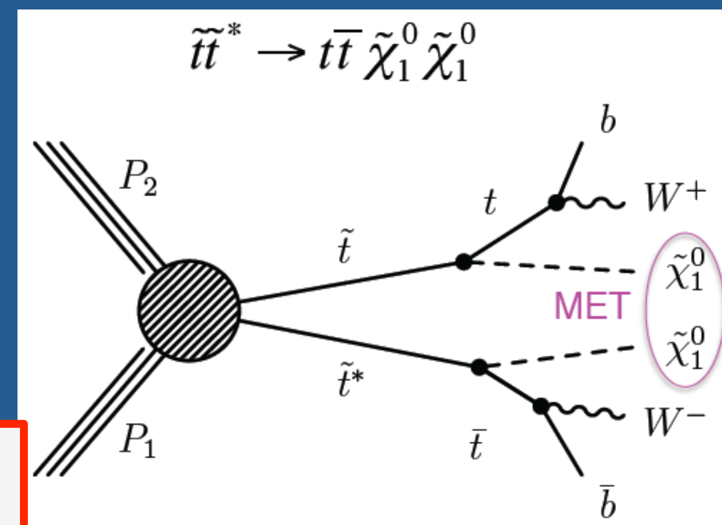
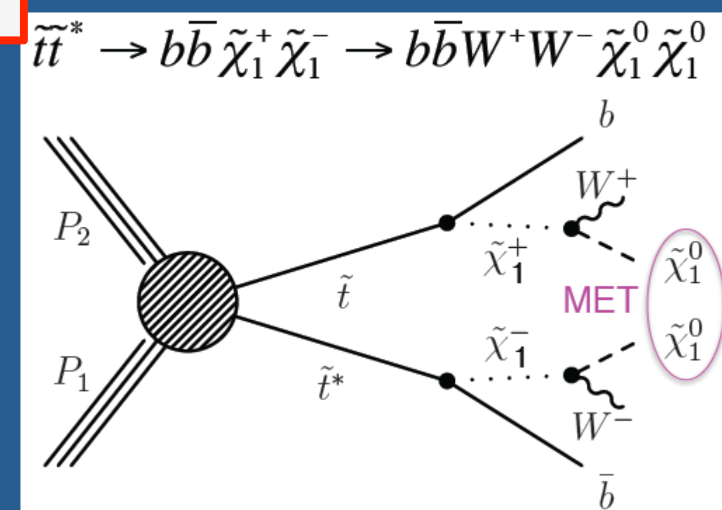


Same final state but different kinematics!

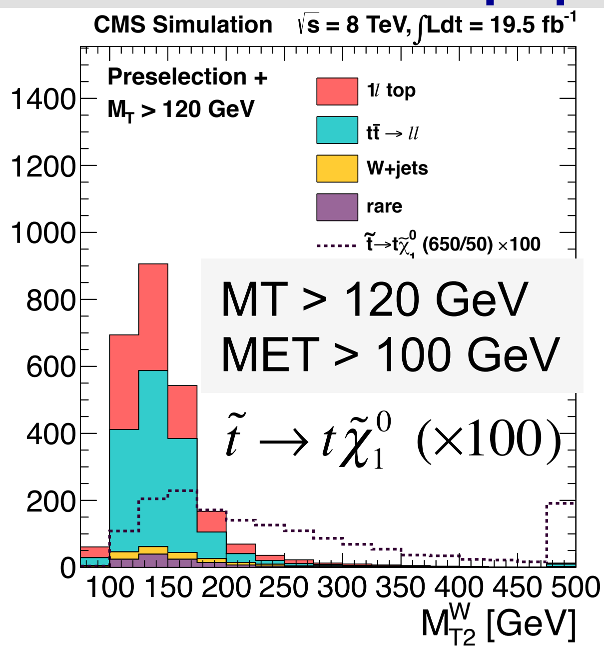


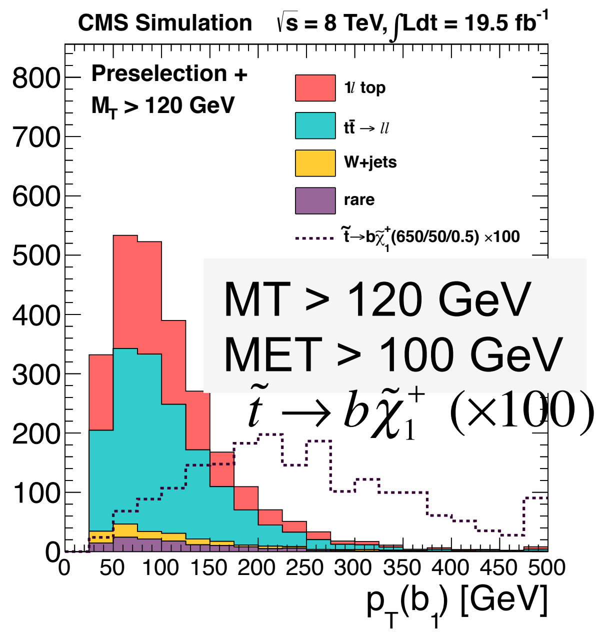


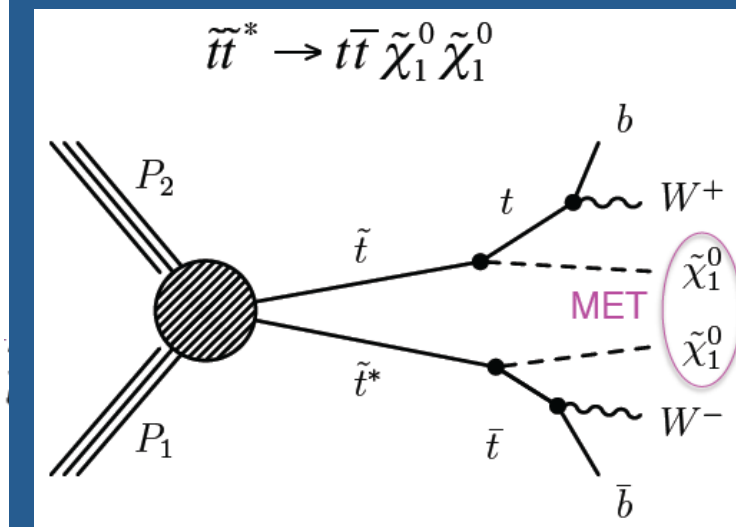
Search for direct stop production: $pp \to \tilde{t}_1 \bar{\tilde{t}}_1$

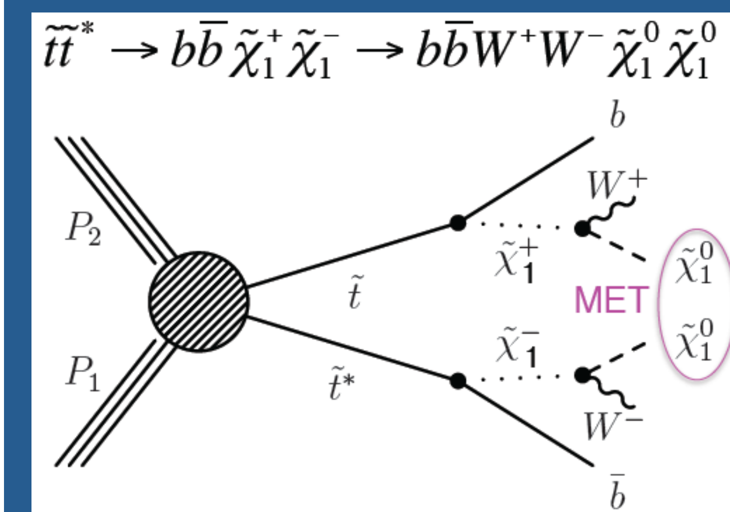
SUS-13-011 **Para** ... **so**

https://twiki.cern.ch/twiki/bin/vie ... v.org/abs/1308.1586







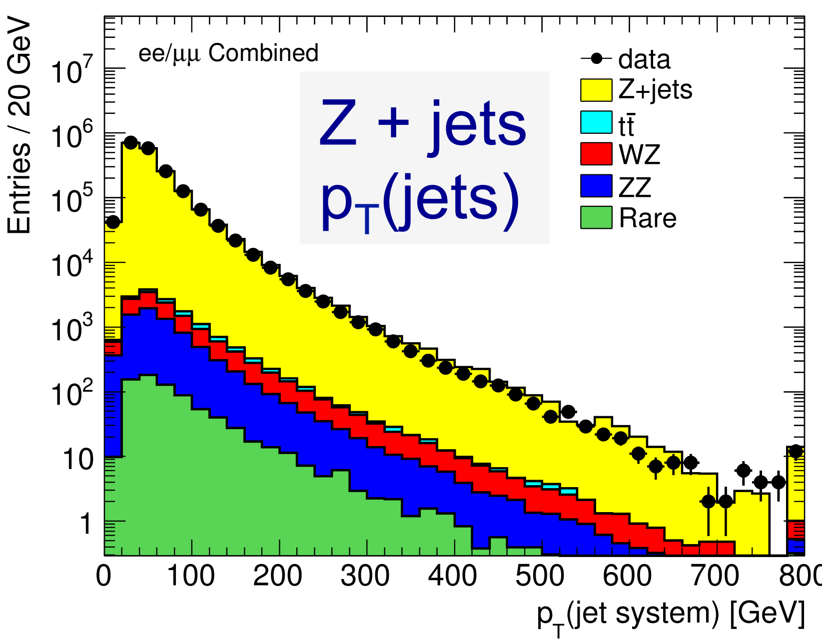


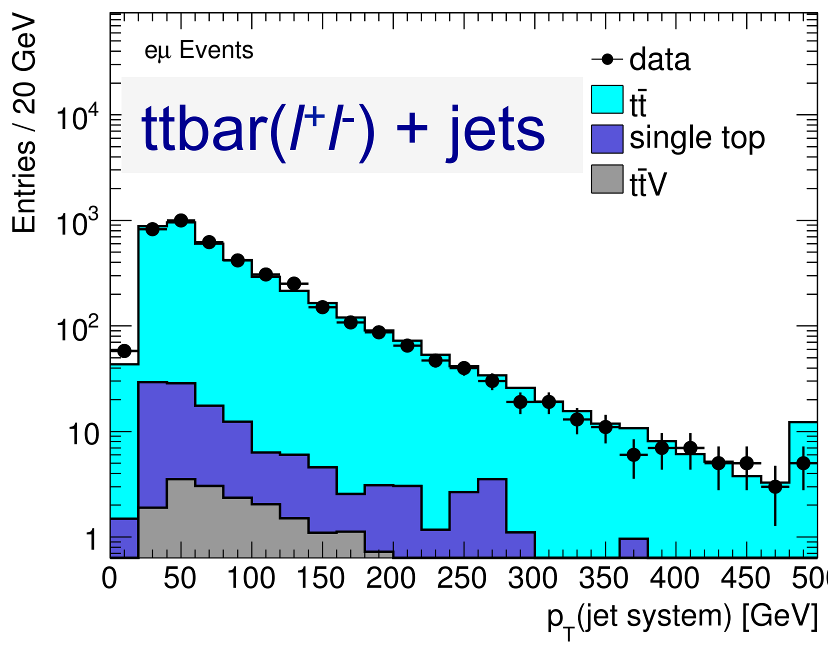
Use BDTs for separate modes & regions.

Search for direct stop: initial state radiation

SUS-13-011

- The effects of initial-state radiation are important for the signal efficiency in the region where MET is small.
- Does the simulation get this right (MADGRAPH) ?
- Study in Z+jets and ttbar.





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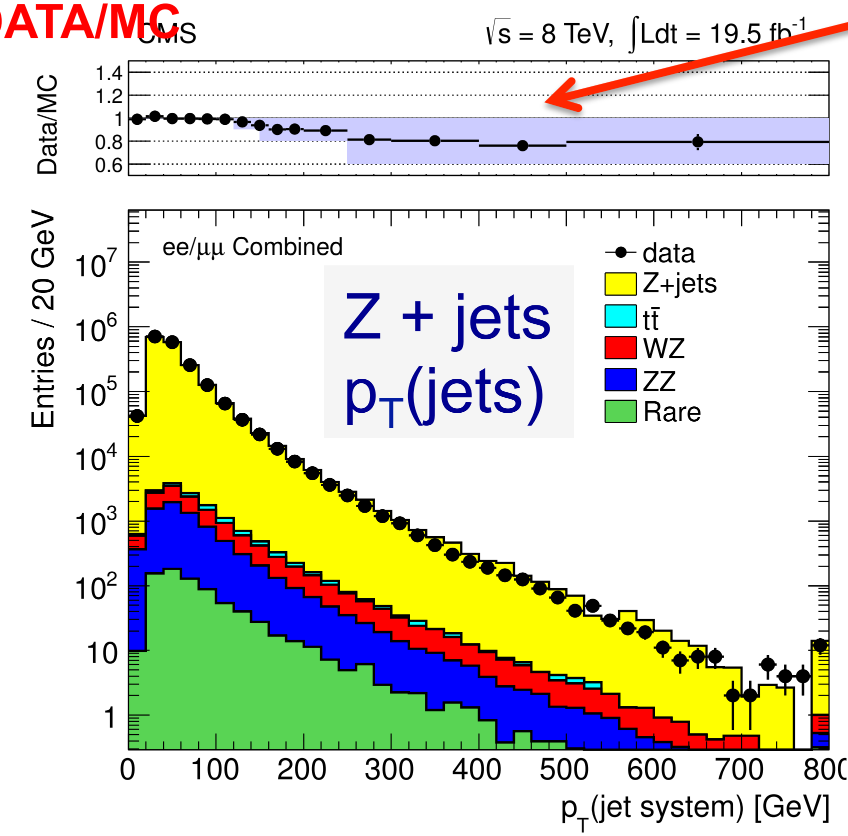
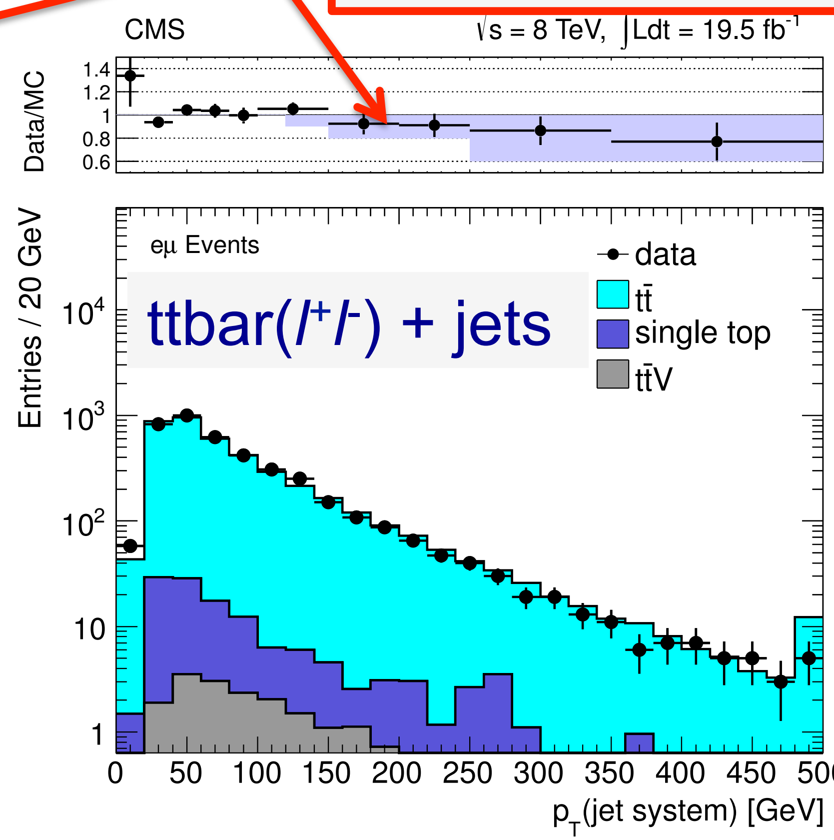
MC predicts up to 20% too much ISR at high pT

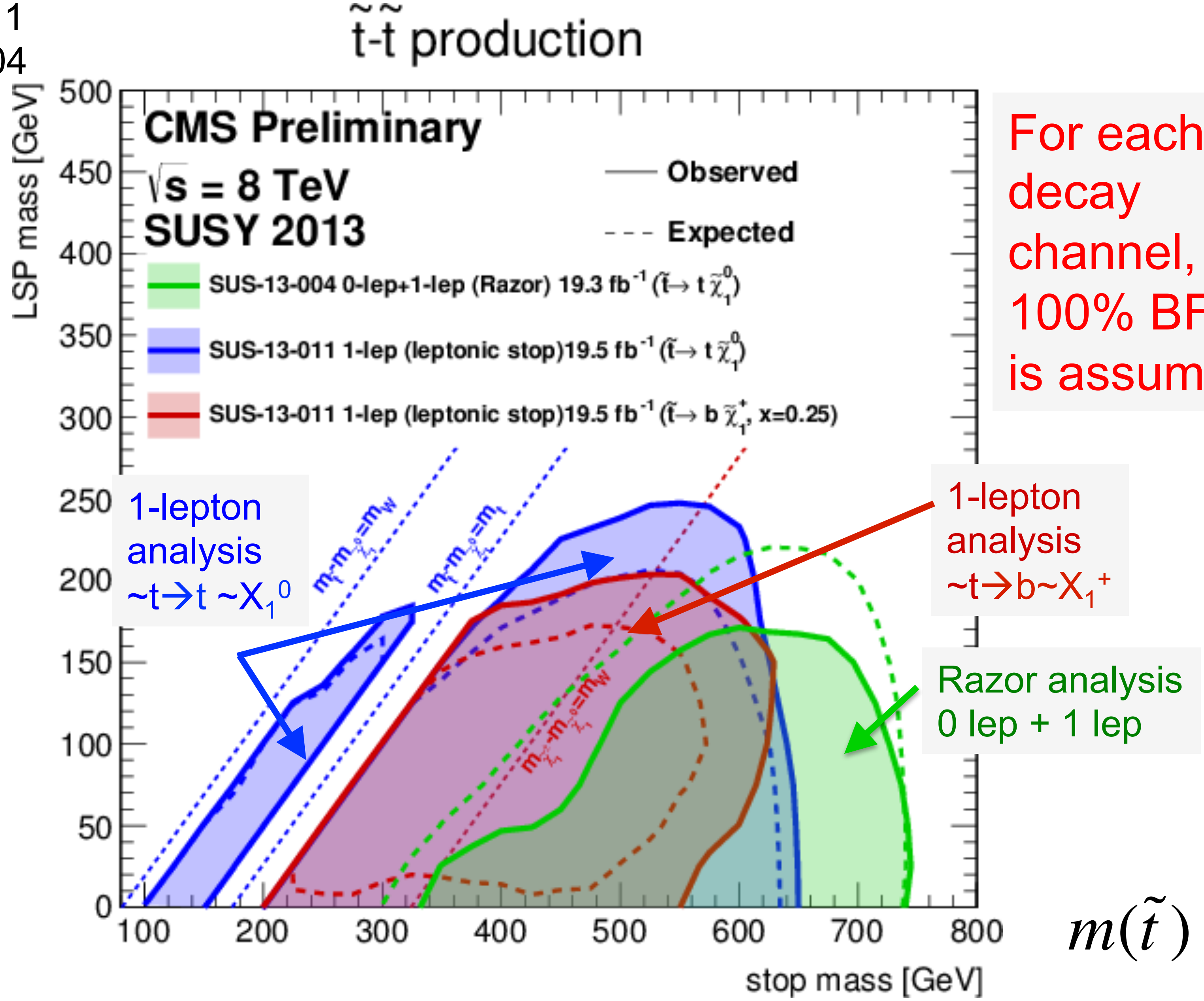
DATA/MC





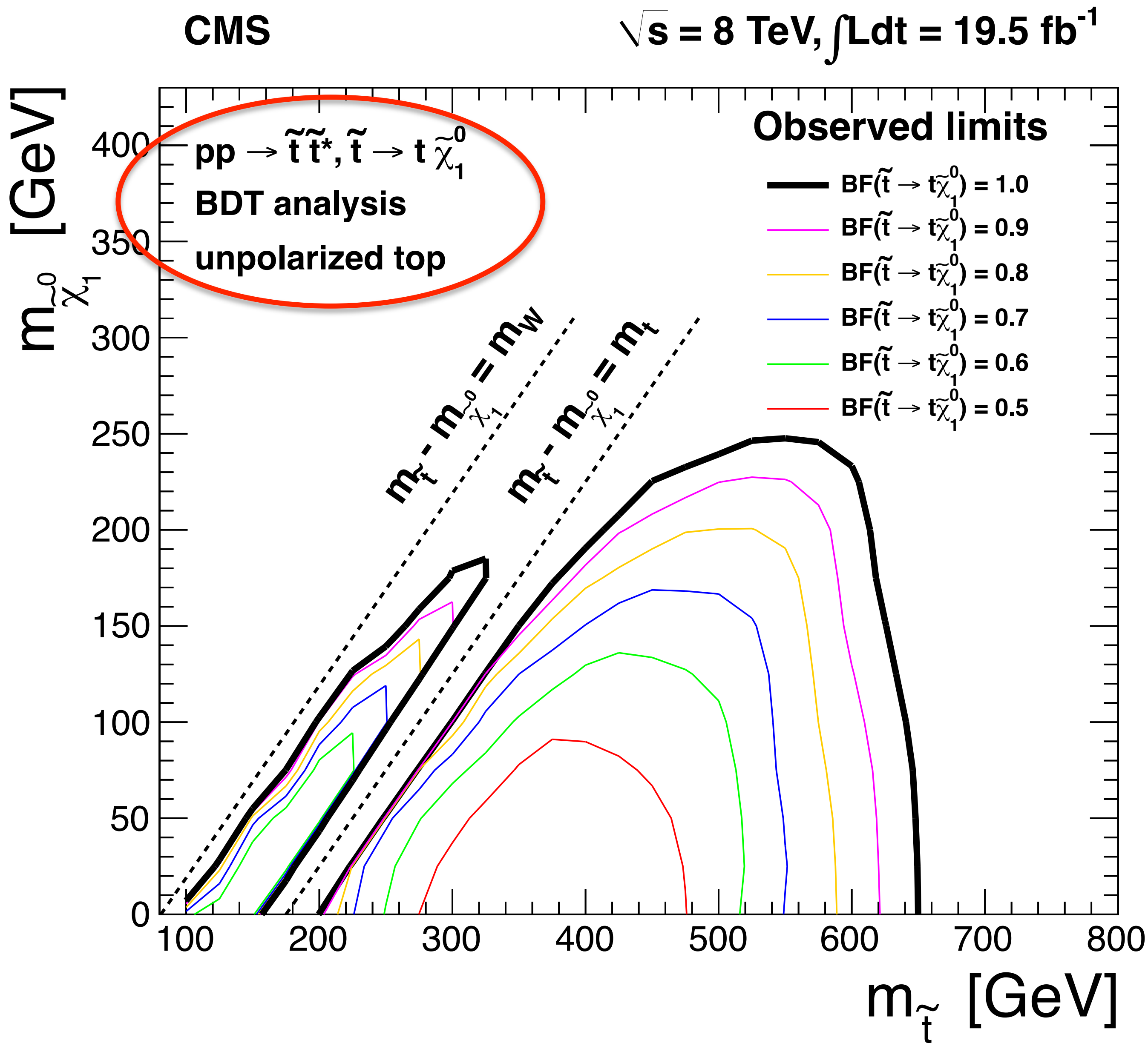
Search for $pp \to \tilde{t}_1 \bar{\tilde{t}}_1$: results

SUS-13-011
SUS-13-004



For each decay channel, 100% BF is assumed!

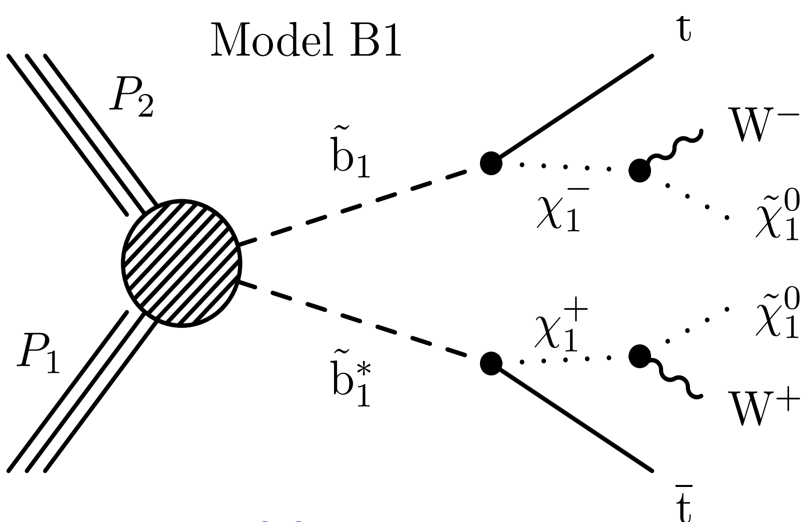
Search for direct stop: dependence on BF

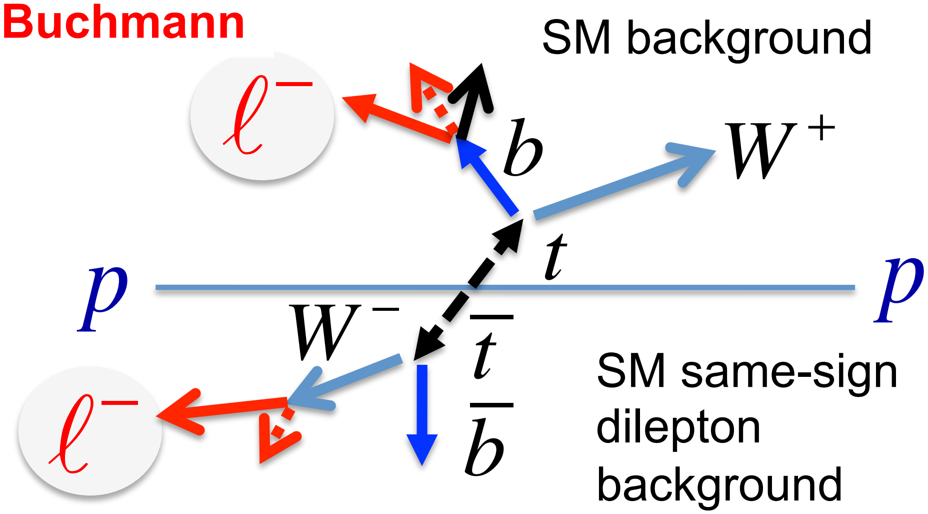


Search for b-jets, same-sign dileptons, MET

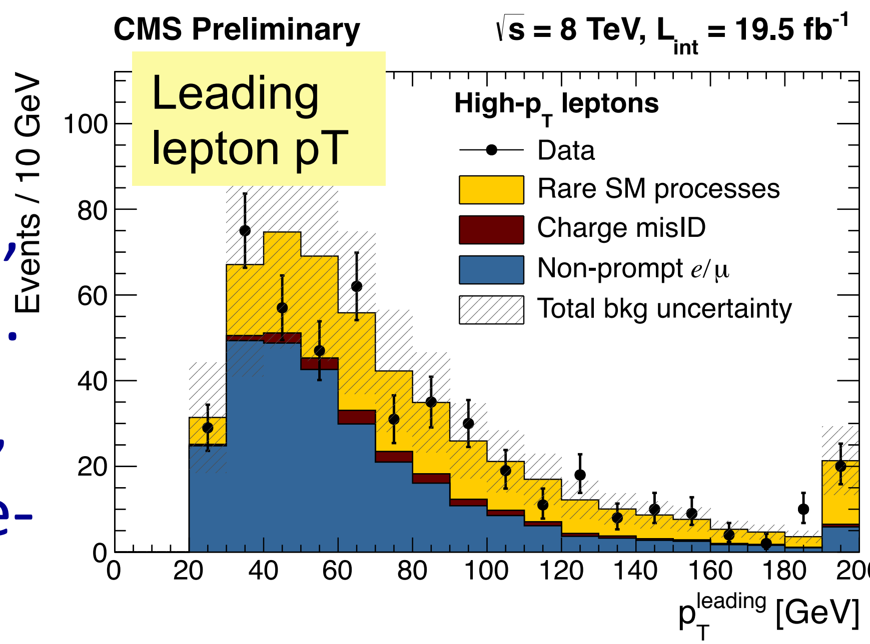
SUS-13-013 https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS13013

Parallel talk: Marco-Andrea Buchmann



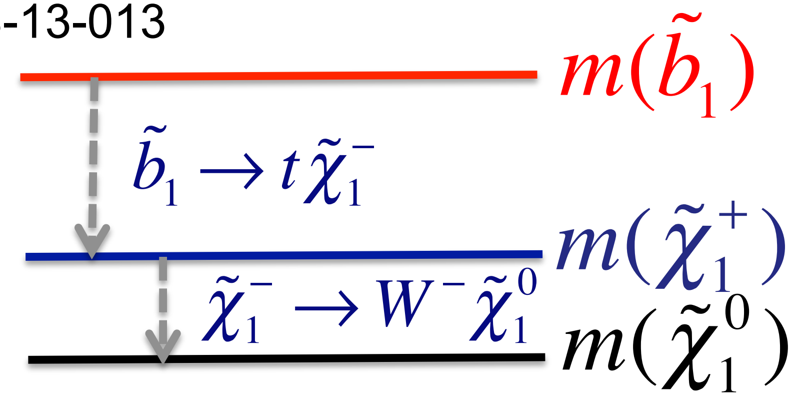


- 54 signal bins!
- N(b) = 0, 1, 2; N(J) =2-3, ≥4, MET bins (50-120,>120 GeV), HT bins (200-400, >400 GeV).
- Sensitivity to direct sbottom, gluino pairs, RPV SUSY, same-sign top, etc.



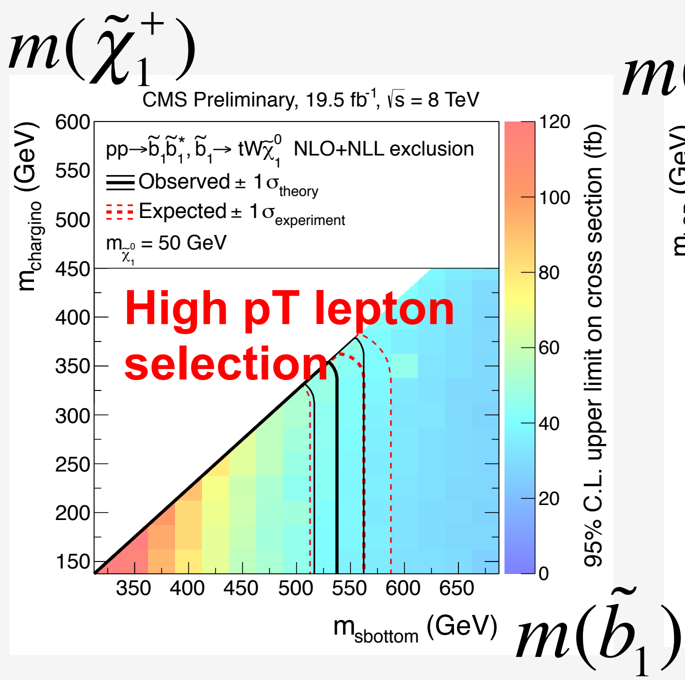
Same-sign dileptons: search for $pp \to \tilde{b}_1 \bar{\tilde{b}}_1$

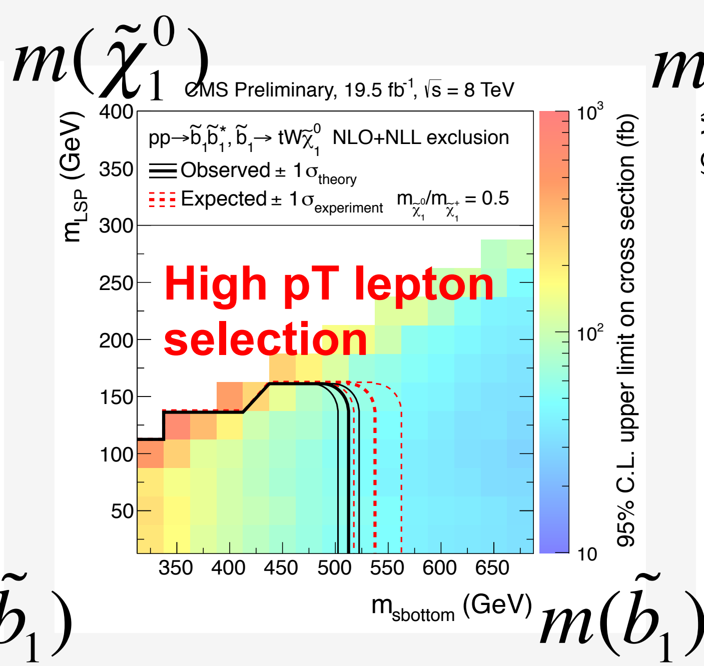
SUS-13-013

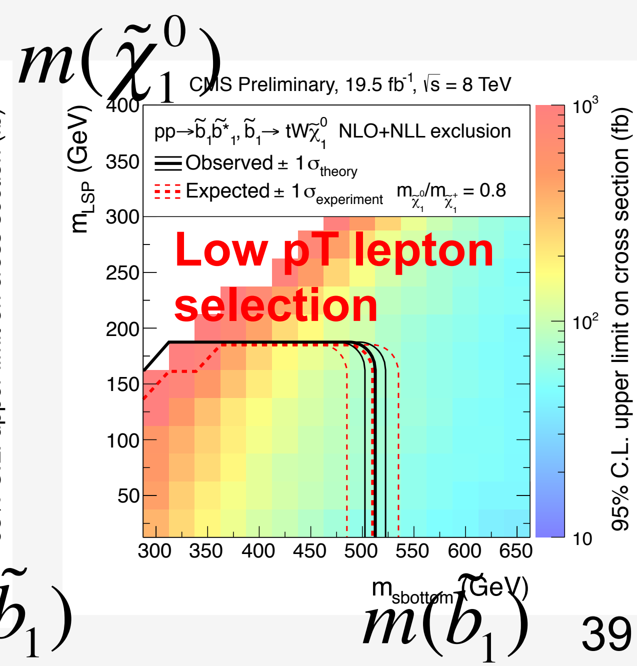


Test how the exclusion region depends on $m(\tilde{\chi}_1^+) - m(\tilde{\chi}_1^0)$

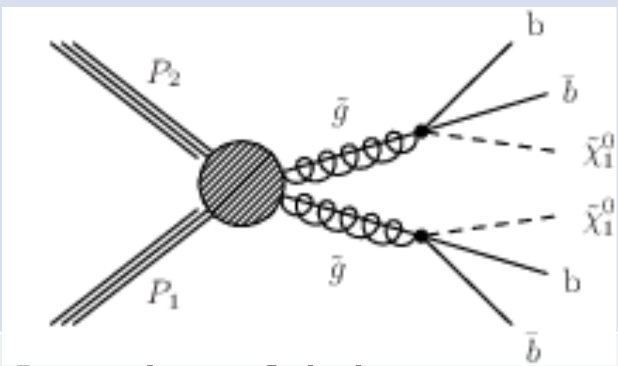
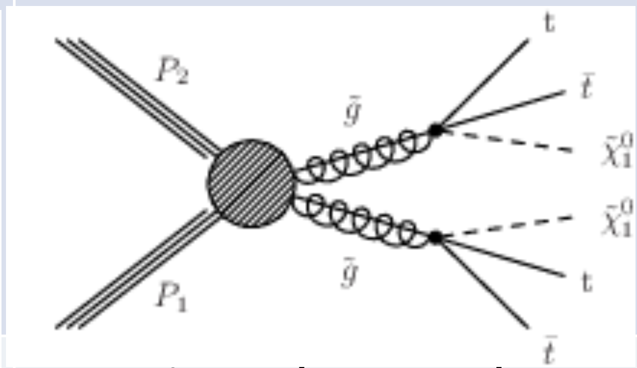
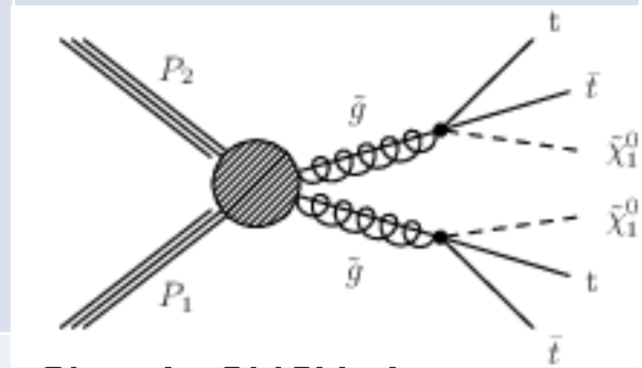
$m(\tilde{\chi}_1^0) = 50$ GeV $\quad m(\tilde{\chi}_1^0)/m(\tilde{\chi}_1^+) = 0.5 \quad m(\tilde{\chi}_1^0)/m(\tilde{\chi}_1^+) = 0.8$







Examples for $pp \rightarrow \tilde{g}\tilde{g}$, $\tilde{g} \rightarrow b\bar{b}\,\tilde{\chi}_1^0, \tilde{g} \rightarrow t\bar{t}\,\tilde{\chi}_1^0$

b-Jets + MET (all hadronic search)	b-Jets + 1 lepton + MET	b-Jets + 2 same-sign leptons + MET
		
Require ≥3 b jets, *no isol leptons*, large MET.	Require 1 lepton, large MET, large N(jets), b jets.	Classic SUSY signature. Key issue is “fake” leptons.
	Off-shell ~t, but also have on-shell interpretation.	

- For many SUSY searches, ttbar is the dominant background.
- Lots of real MET from W decays
- b-tagging suppresses Z + jets, W + jets.

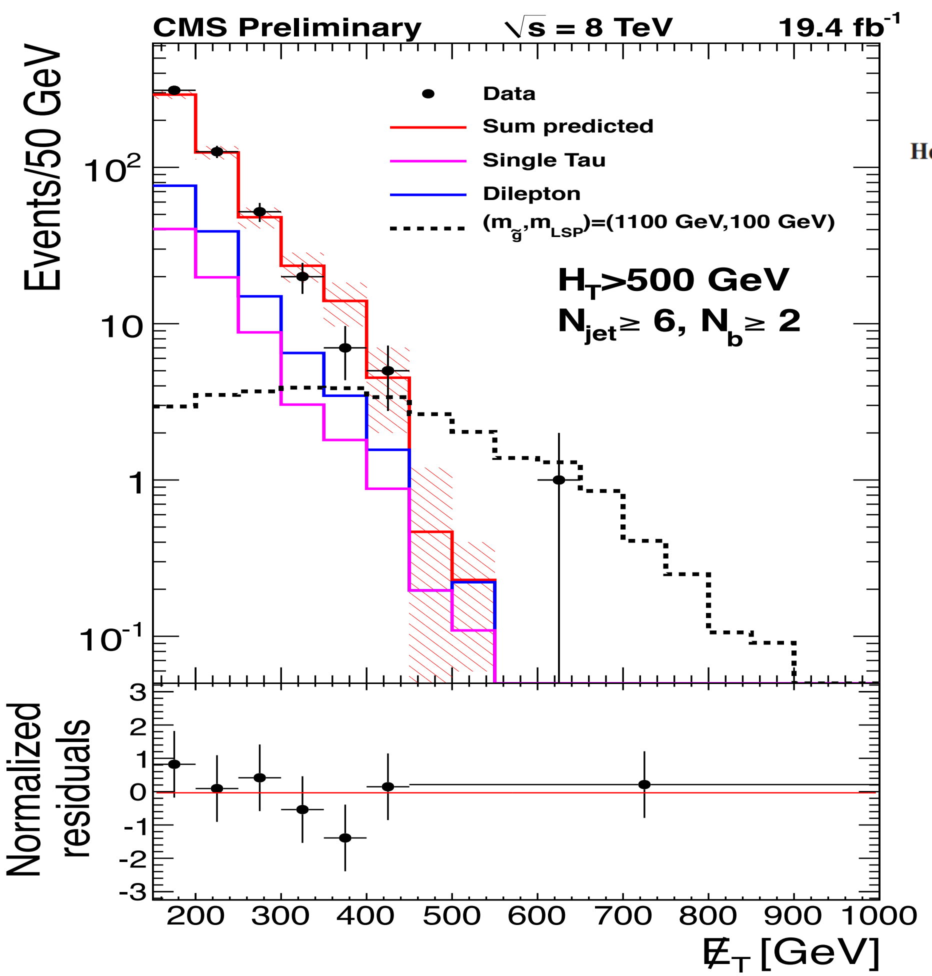
SUSY search for b-jets, 1 lepton, and MET

CMS PAS SUS-13-007

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS13007

Parallel talk: Marco-Andrea Buchmann

Lepton spectrum method: for leptons produced in W decay, the lepton spectrum can be used to measure the ν spectrum.



Makes use of W helicity fractions in t→bW

PHYSICAL REVIEW D **81,** 111503(R) (2010)

Helicity fractions of *W* bosons from top quark decays at next-to-next-to-leading order in QCD

Andrzej Czarnecki*

Department of Physics, University of Alberta, Edmonton, Alberta T6G 2G7, Canada and CERN Theory Division, CH-1211 Geneva 23, Switzerland

Jürgen G. Körner†

Institut für Physik, Universität Mainz, 55099 Mainz, Germany

Jan H. Piclum‡

Department of Physics, University of Alberta, Edmonton, Alberta T6G 2G7, Canada

(Received 13 May 2010; published 18 June 2010)

Decay rates of unpolarized top quarks into longitudinally and transversally polarized *W* bosons are calculated to second order in the strong coupling constant α_s. Including the finite bottom quark mass and electroweak effects, the standard model predictions for the *W*-boson helicity fractions are $\mathcal{F}_L = 0.687(5)$, $\mathcal{F}_+ = 0.0017(1)$, and $\mathcal{F}_- = 0.311(5)$.

...and W helicity fractions in W+jets

PHYSICAL REVIEW D **84,** 034008 (2011)

Left-handed *W* bosons at the LHC

Z. Bern,[1] G. Diana,[2] L. J. Dixon,[3,4] F. Febres Cordero,[5] D. Forde,[3,6] T. Gleisberg,[4] S. Höche,[4] H. Ita,[1] D. A. Kosower,[2] D. Maître,[3,7] and K. Ozeren[1]

The production of *W* bosons in association with jets is an important background to new physics at the LHC. Events in which the *W* carries large transverse momentum and decays leptonically lead to large missing energy and are of particular importance. We show that the left-handed nature of the *W* coupling, combined with valence quark domination at a *pp* machine, leads to a large left-handed polarization for both W^+ and W^- bosons at large transverse momenta. The polarization fractions are very stable with

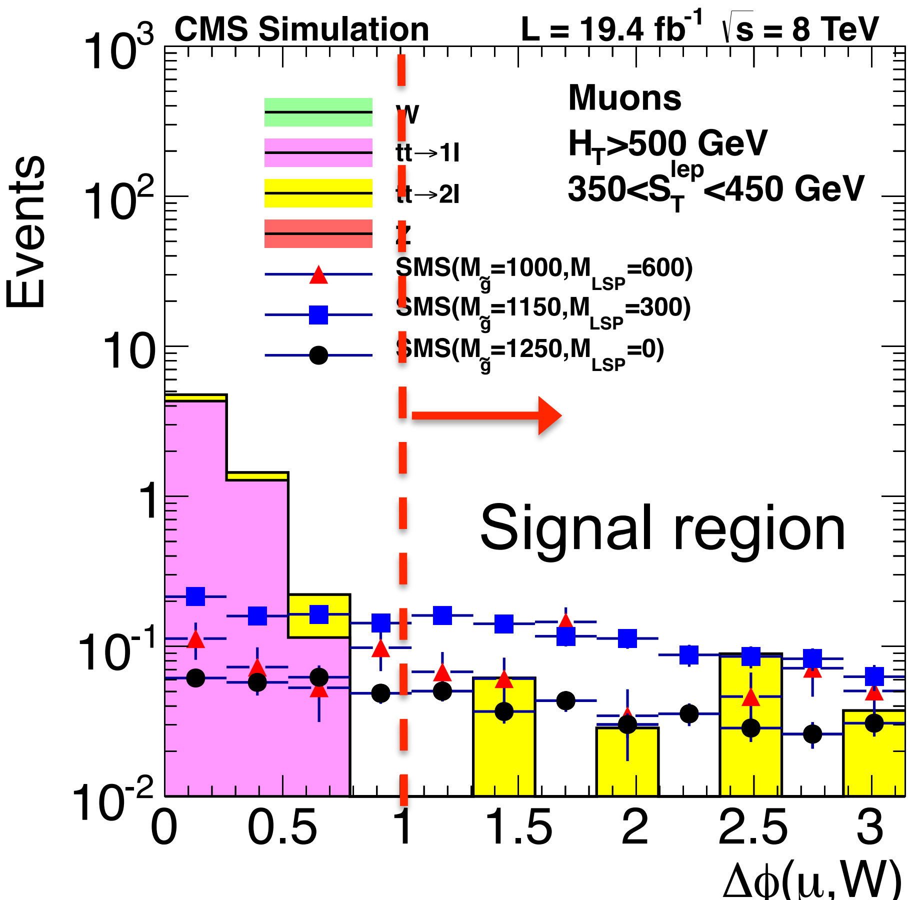
SUSY search for b-jets, 1 lepton, and MET

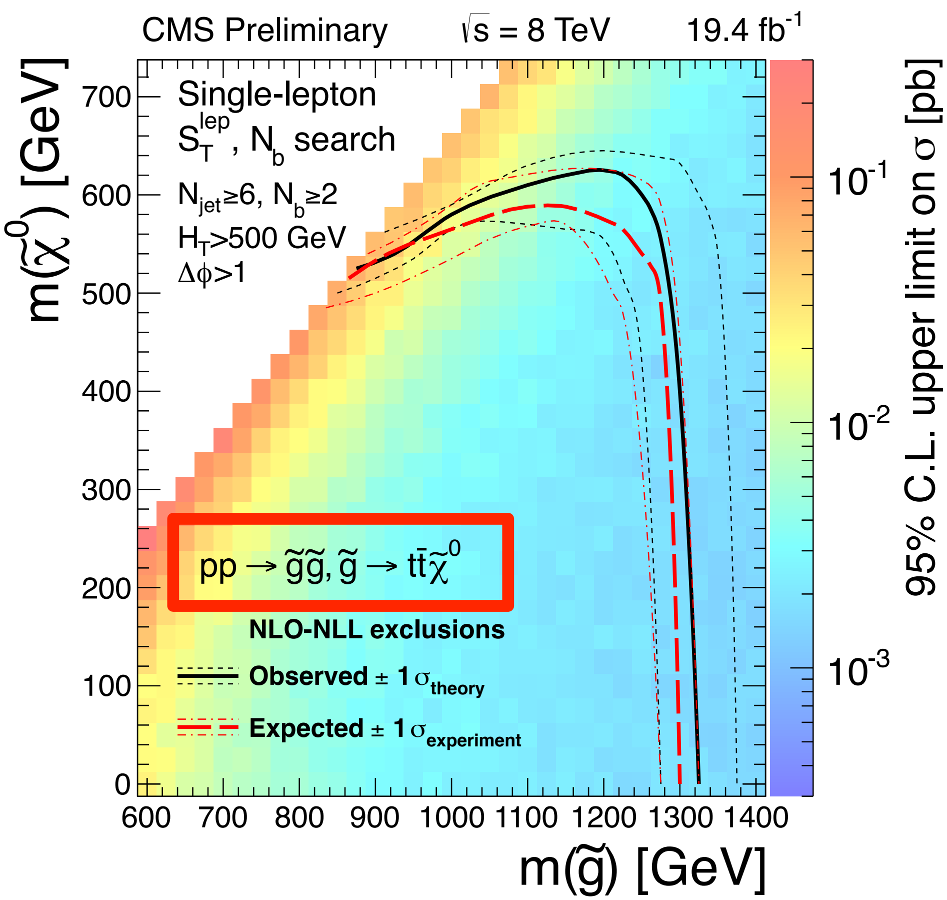
CMS PAS SUS-13-007

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS13007

Parallel talk: Marco-Andrea Buchmann

$\Delta\varphi$(lepton, W) method: strong suppression of 1-lepton background (similar to MT). Also use ST = pT(lep) + MET.





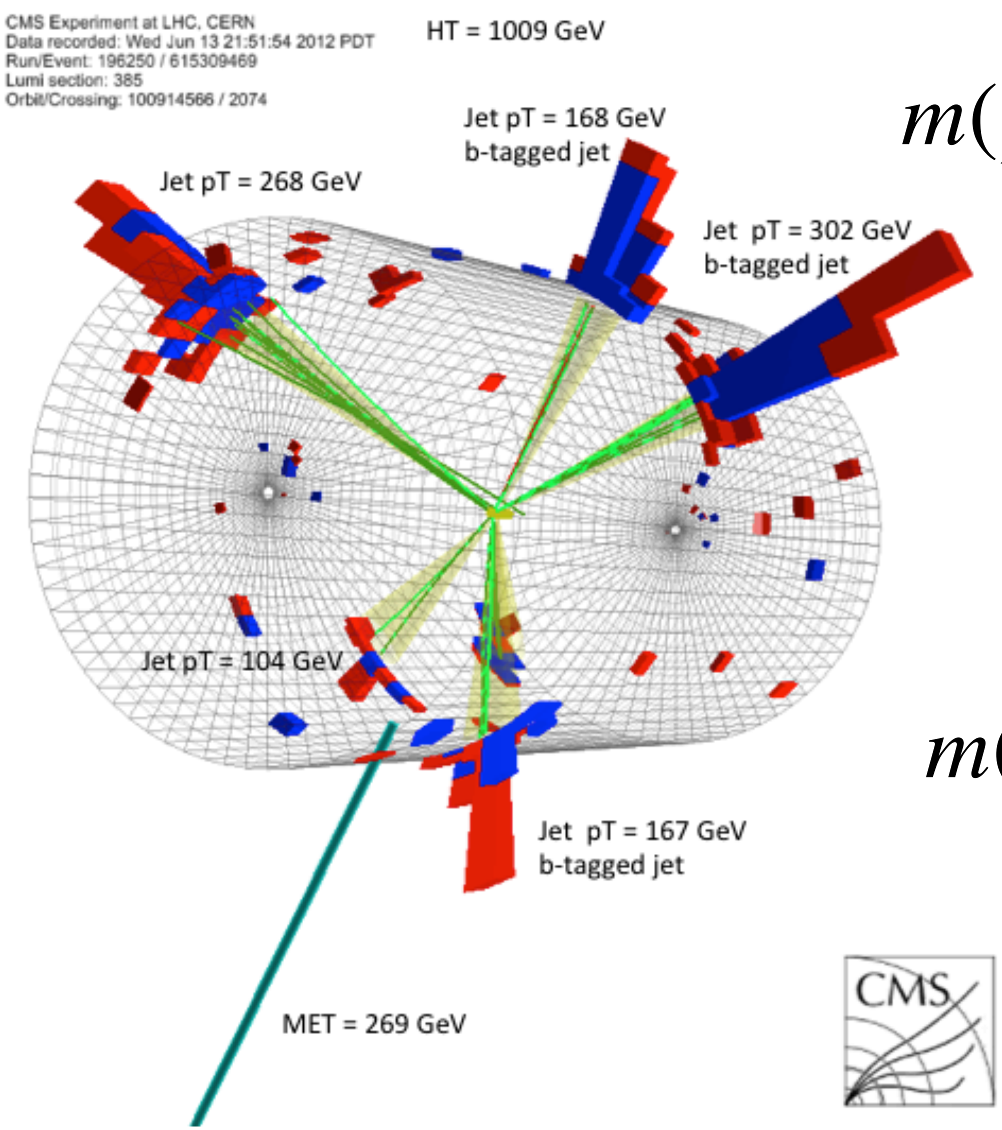
Optimized for gluino pair production: N(J)≥6 and N(b)≥2.

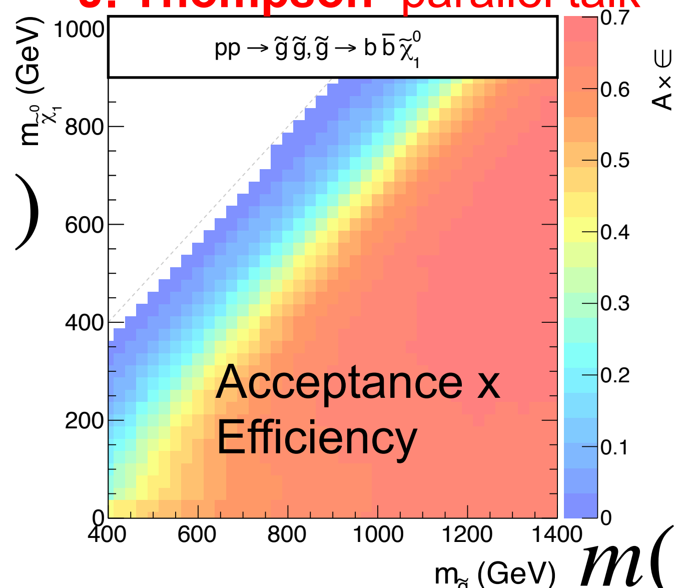
Search for b-jets & MET: $pp \to \tilde{g}\tilde{g},\ \tilde{g} \to b\bar{b}\,\tilde{\chi}_1^0$

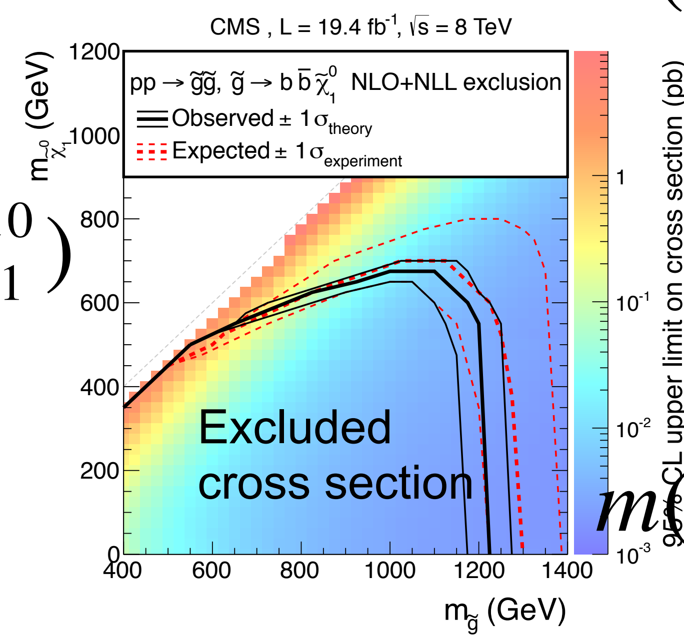
SUS-12-024 http://arxiv.org/abs/1305.2390

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS12024

J. Thompson parallel talk







Search for b-jets and MET with razor variables

SUS-13-004 https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS13004

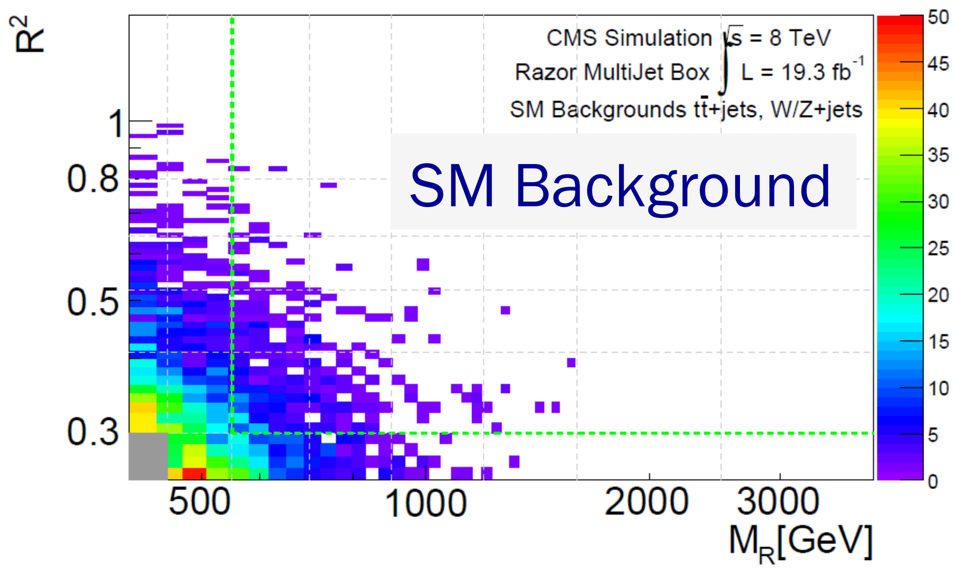
- "Razor" kinematic variables *C. Rogan, arXiv:1006.2727*

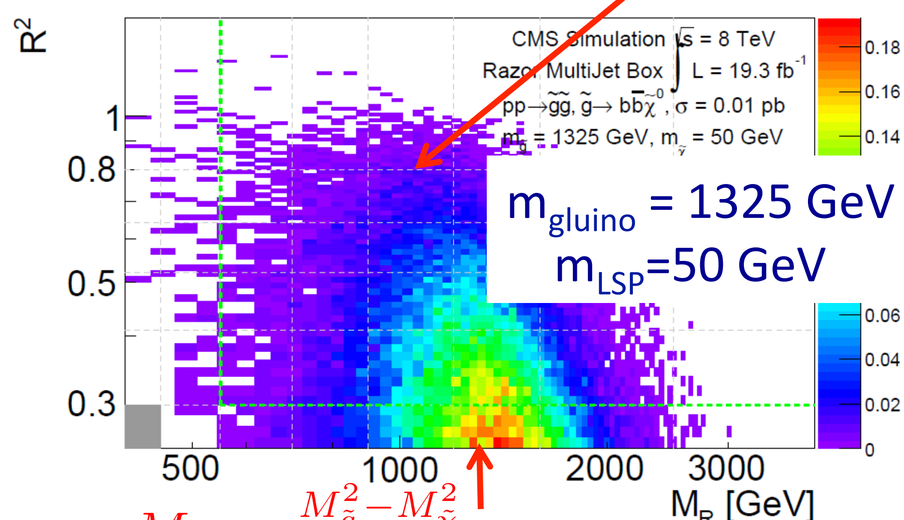
$$M_R \equiv \sqrt{(p_{j_1} + p_{j_2})^2 - (p_z^{j_1} + p_z^{j_2})^2}$$

$$M_T^R \equiv \sqrt{\frac{E_T^{miss}(p_T^{j1} + p_T^{j2}) - \vec{E}_T^{miss} \cdot (\vec{p}_T^{\,j1} + \vec{p}_T^{\,j2})}{2}} \qquad R \equiv \frac{M_T^R}{M_R}$$

- Variables defined in terms of a dijet topology. For higher multiplicity, cluster jets into 2 pseudojets.

Signal has tail at high R^2



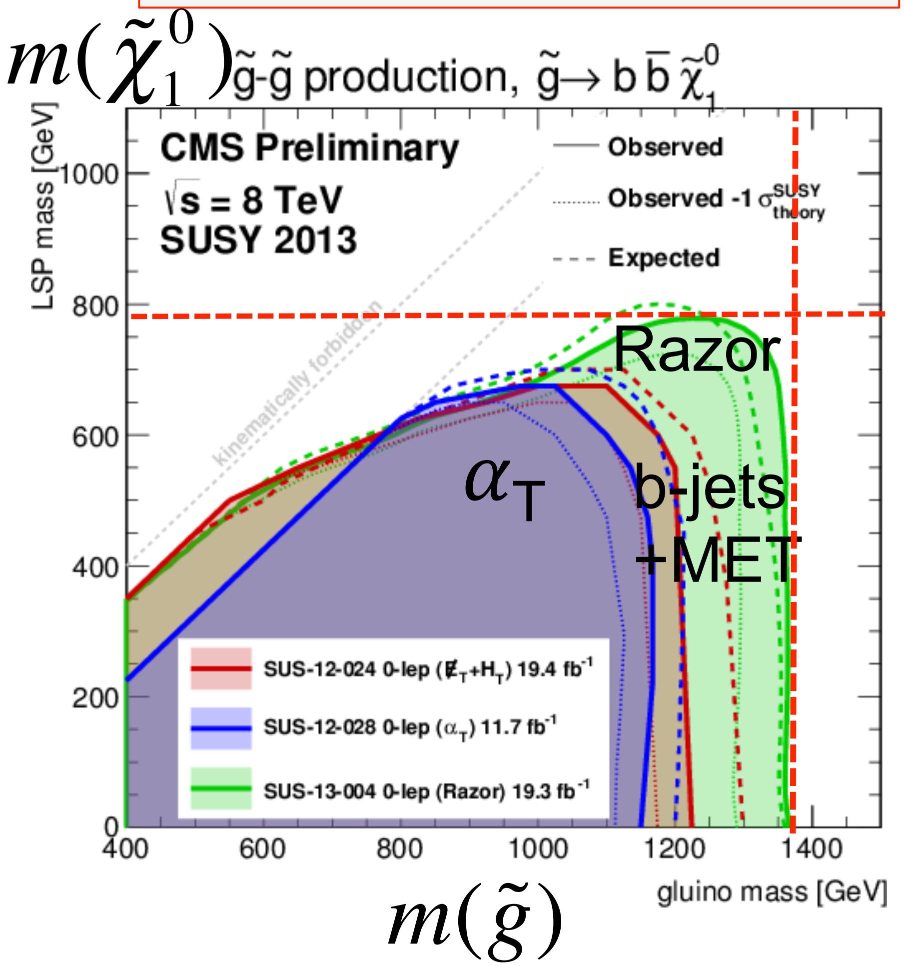


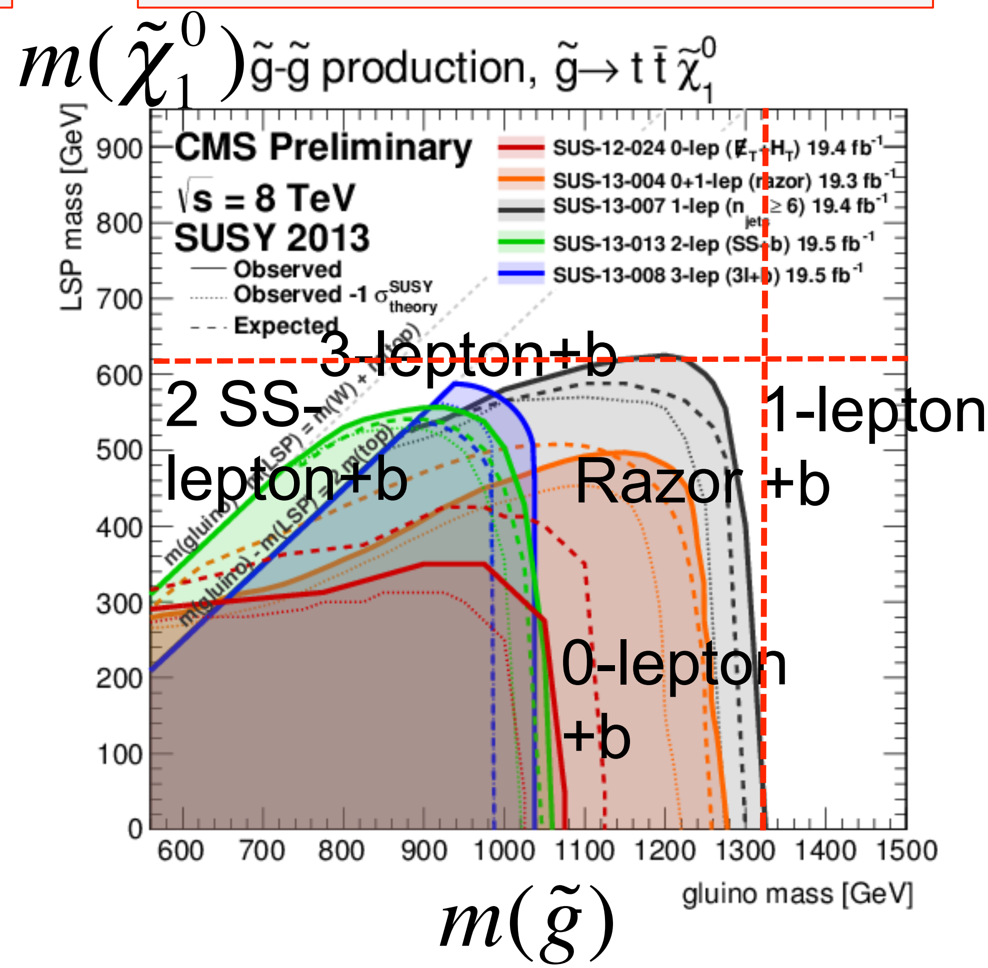
$$M_\Delta = \frac{M_{\tilde{g}}^2 - M_{\tilde{\chi}}^2}{M_{\tilde{g}}}$$

Searches for gluino pair production (→b-jets)

4b + MET final state:
hadronic searches most sensitive.

4t + MET final state:
single lepton search most sensitive.





No exclusion for M(LSP) ≳ 750 GeV.
Strongest limit: m(~g) ≳ 1375 GeV.

No exclusion for M(LSP) ≳ 600 GeV.
Strongest limit: m(~g) ≳ 1320 GeV.

Outline

- Big themes and challenges for SUSY searches
- Inclusive (generic) searches
- Naturalness-inspired searches: $\tilde{t}\,,\, \tilde{b}\,,\, \tilde{g}$
- Search for EWKinos & sleptons $\tilde{\chi}_i^0\,,\, \tilde{\chi}_j^{\pm}\,,\, \tilde{\ell}$
- SUSY decays with Higgs
- Multi-lepton and R-parity violating signatures
- Conclusions

Drawing courtesy Sergio Cittolin

CMS PUBLIC SUSY RESULTS
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

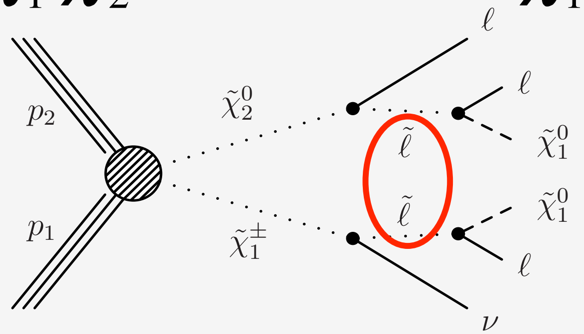
New results in all of these areas. Analyses use 19.5 fb^{-1} ($\sqrt{s}$ =8 TeV).

Electroweak production: $\tilde{\chi}_i^0$, $\tilde{\chi}_j^\pm$, and $\tilde{\ell}^\pm$

SUS-13-006 https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS13006

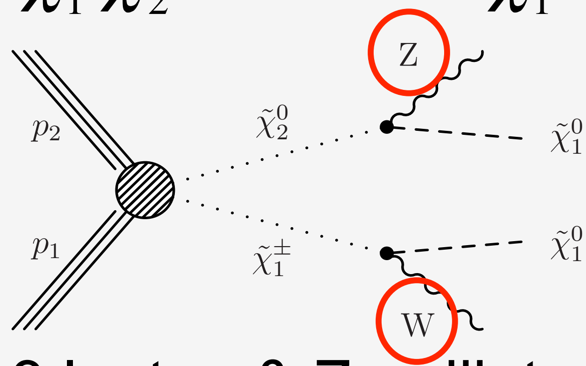
Parallel talk: Ben Hooberman

$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow 3\ell + \nu + 2\tilde{\chi}_1^0$



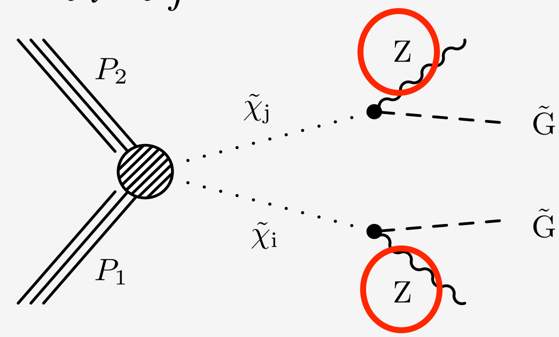
3 lep & SS dileptons

$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow WZ + 2\tilde{\chi}_1^0$



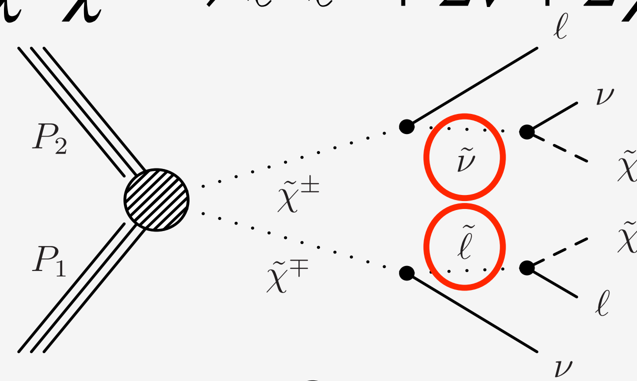
3 lepton & Z + dijet

$\tilde{\chi}_i^0 \tilde{\chi}_j^0 \rightarrow ZZ + 2\tilde{G}$

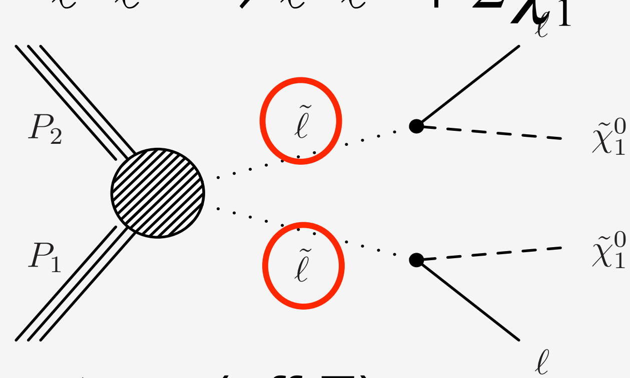


3 lep, 4 lep, Z dijet

$\tilde{\chi}^\pm \tilde{\chi}^\mp \rightarrow \ell^+\ell^- + 2\nu + 2\tilde{\chi}_1^0$



$\tilde{\ell}^+\tilde{\ell}^- \rightarrow \ell^+\ell^- + 2\tilde{\chi}_1^0$



Opposite-sign dileptons (off Z)

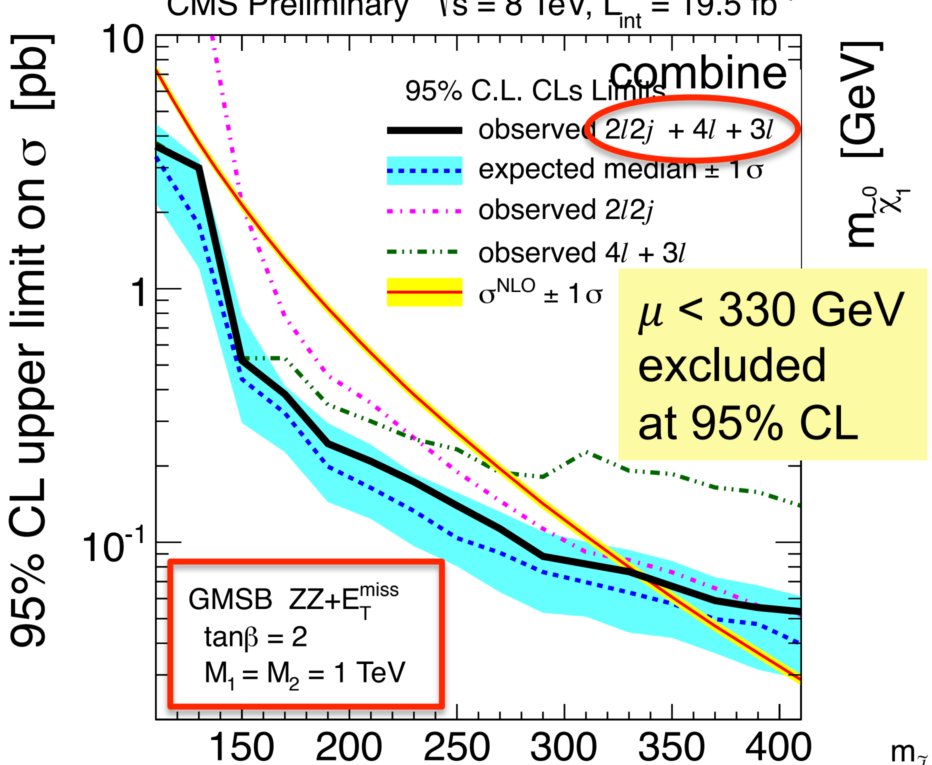
Results: Electroweak production of $\tilde{\chi}_i^0$, $\tilde{\chi}_j^\pm$

SUS-13-006 https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS13006

Parallel talk: Ben Hooberman

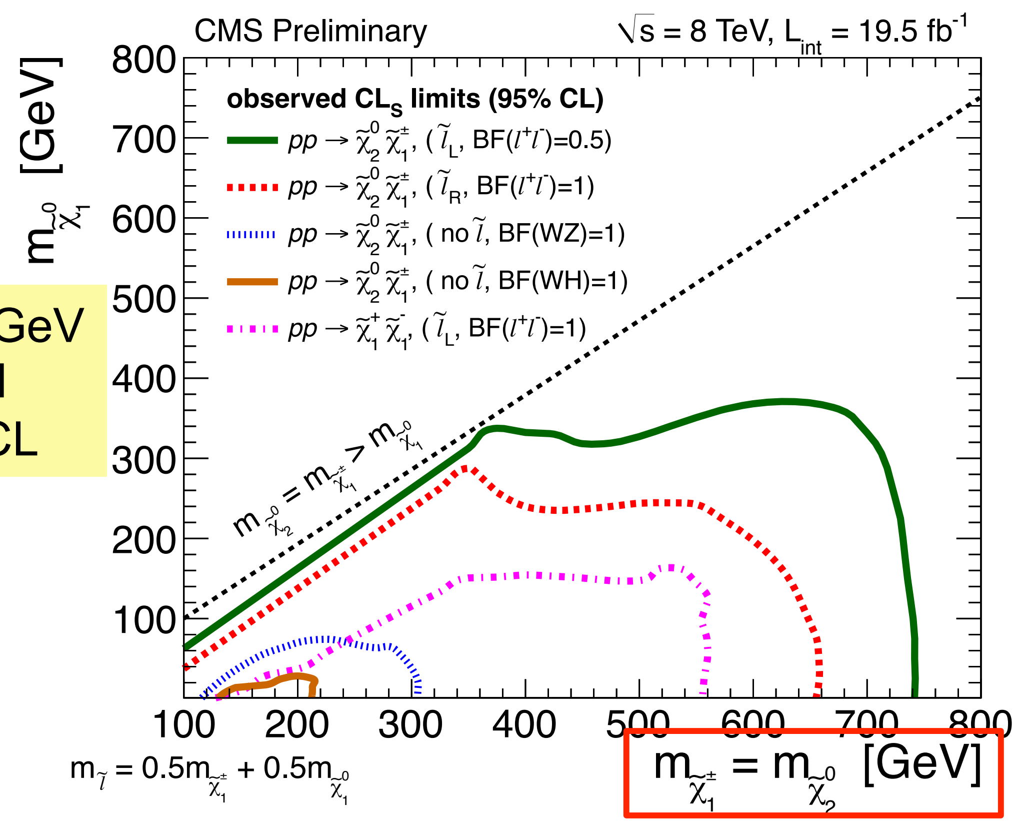
GMSB Z-enriched higgsino scenario

$$\tilde{\chi}_1^0\tilde{\chi}_1^0 \to (Z\tilde{G})(Z\tilde{G})$$



$m(\tilde{\chi}_1^0) \approx m(\tilde{\chi}_2^0) \approx m(\tilde{\chi}_1^\pm) \approx \mu$

Chargino-Neutralino production/decay scenarios

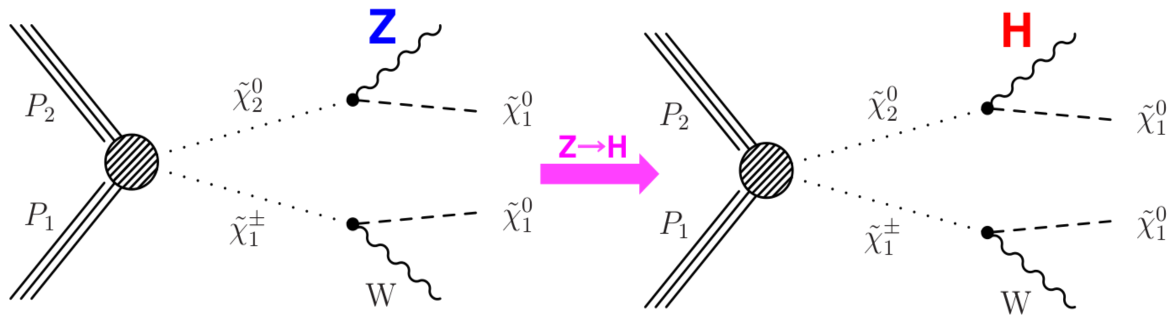


EWK production of $\tilde{\chi}^{\pm}, \tilde{\chi}^{0}$: Higgs final states

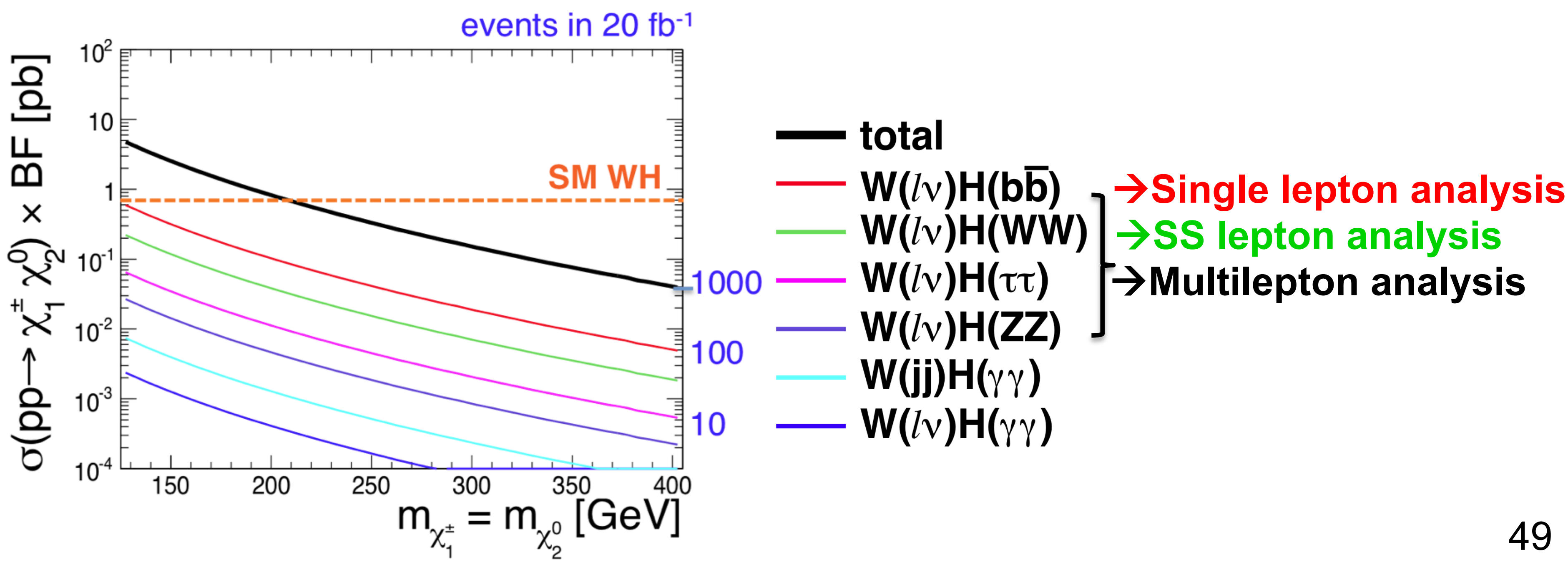
SUS-13-017 https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS13017

Parallel talk: Ben Hooberman

Natural SUSY models suggest higgsinos are light.
Search for WH +MET in three channels (1 lepton, SS dilepton, multilepton)



$$pp \to \tilde{\chi}_1^{\pm} \tilde{\chi}_2^{0}$$
$$\to W^{\pm} \tilde{\chi}_1^{0} + H \tilde{\chi}_1^{0}$$



EWK production of $\tilde{\chi}^{\pm}, \tilde{\chi}^{0}$: Higgs final states

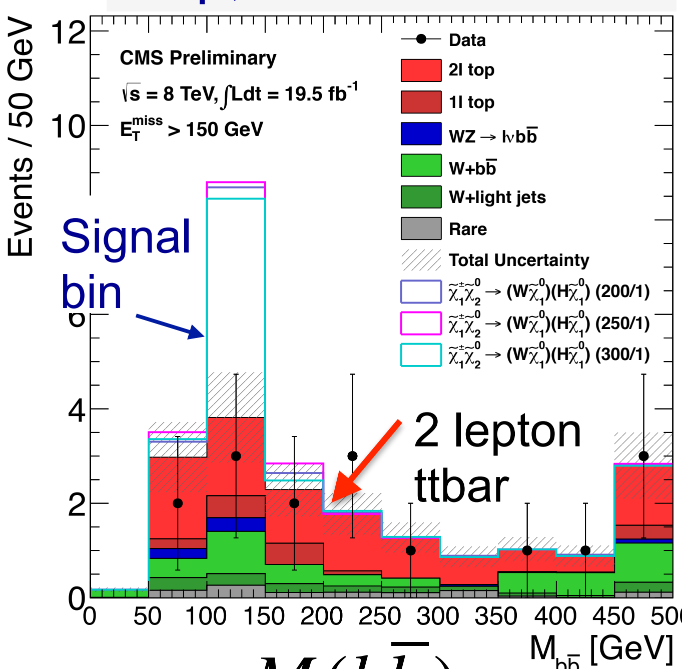
SUS-13-017

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS13017

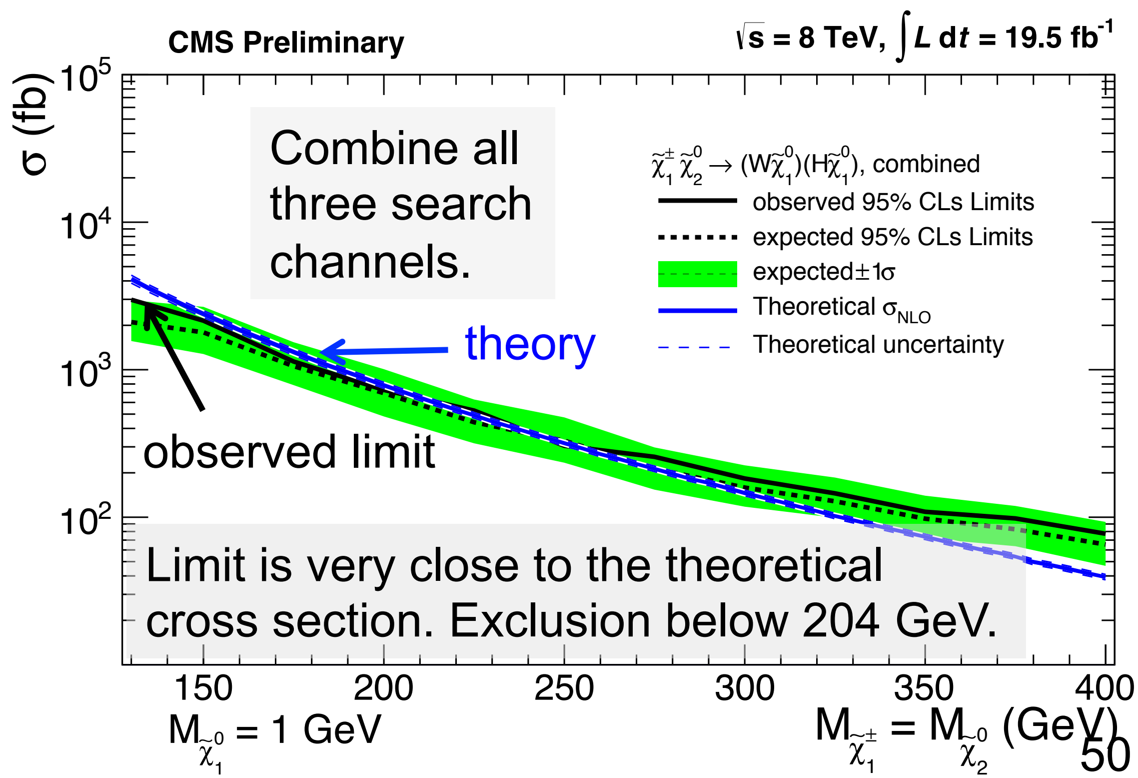
Parallel talk: Ben Hooberman

1-lepton channel W(*l* nu) + H(bb) + MET	Same-sign dileptons W(l n) + H(WW) + MET	Multilepton channels W(l nu) + H(WW, ZZ, $\tau\tau$)+MET
1 lepton, <u>exactly 2 jets</u>, both b jets, kinematic cuts, MET, SIGNAL: m(bb)	2 same-sign leptons, 2-3 jets, no b-jets, kin. cuts, SIGNAL m(l, J1, J2) <120	Mainly: 3 leptons, low HT, and no b-tagged jets.

1 lep, MET > 150 GeV



$M(b\bar{b})$



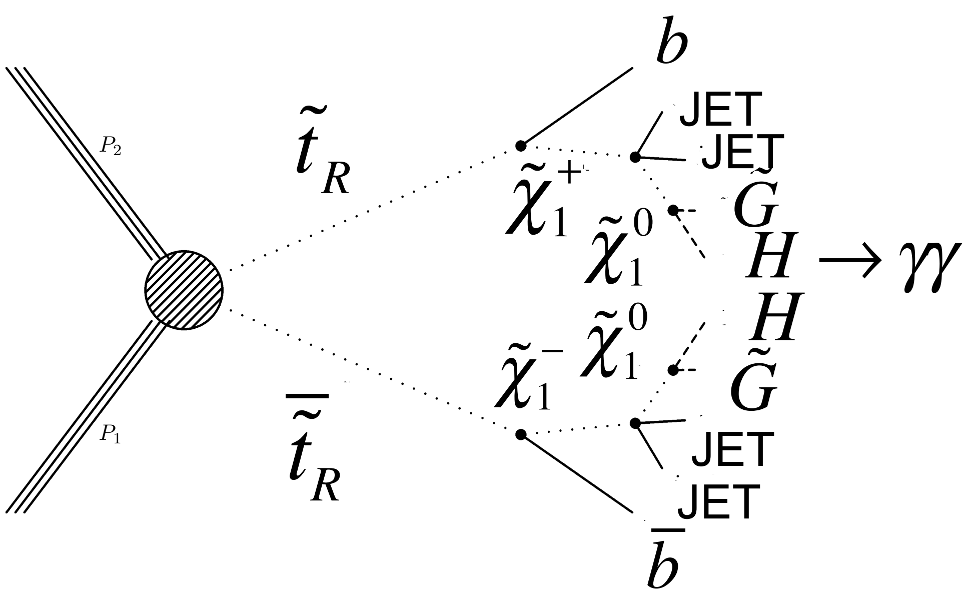
Search for $\tilde{t}$ and $\tilde{\chi}^0$ in H→$\gamma\gamma$ final states

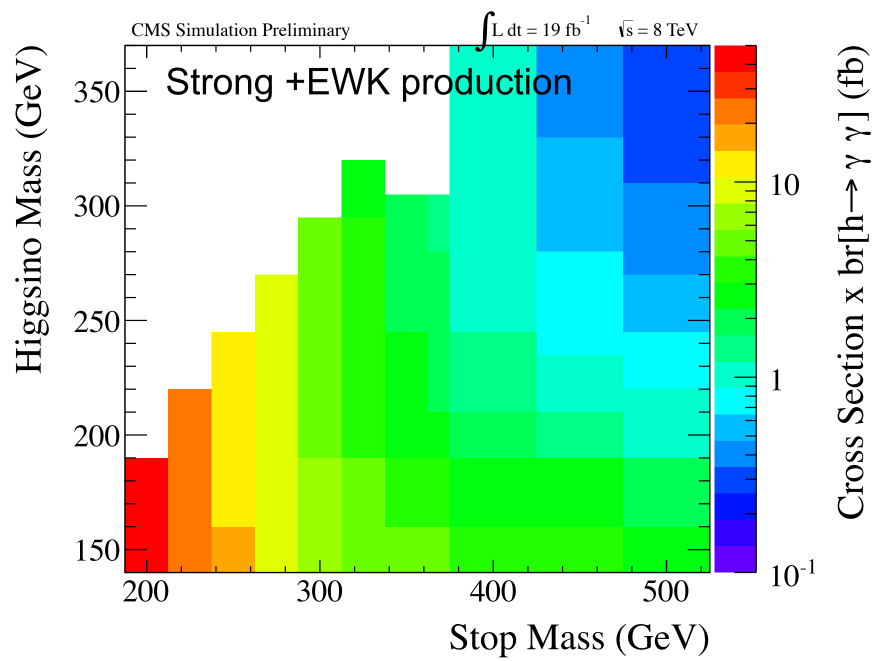
SUS-13-014

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS13014

Parallel talk: David Morse

- Up until now, CMS searches for GMSB photon signatures have been searches for inclusive Jets + MET + 1-2 photons.
- Now look for naturalness motivated signature in GMSB





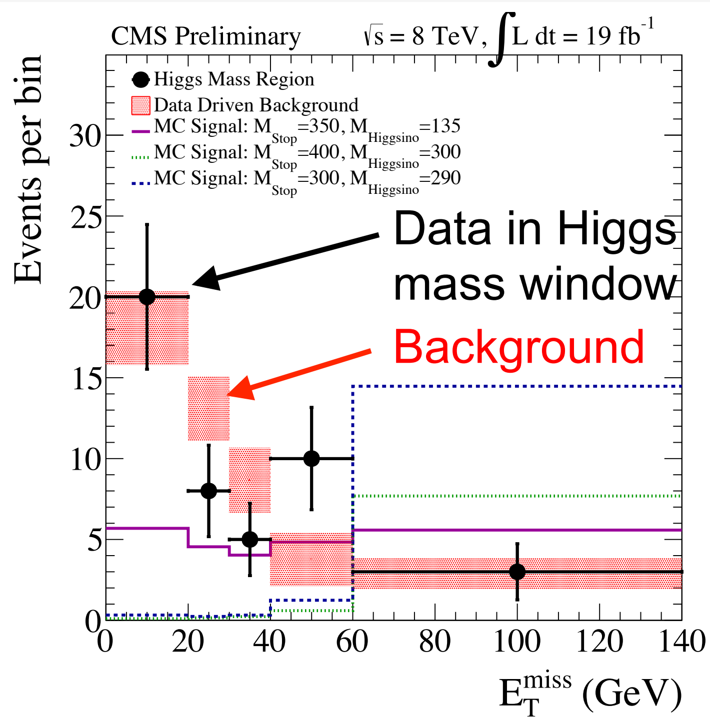
- σ×B(H→$\gamma\gamma$) can lead to significant number produced events!
- QCD background: $\gamma\gamma$ + b$\bar{b}$ & 1γ + b$\bar{b}$ + jet faking γ.

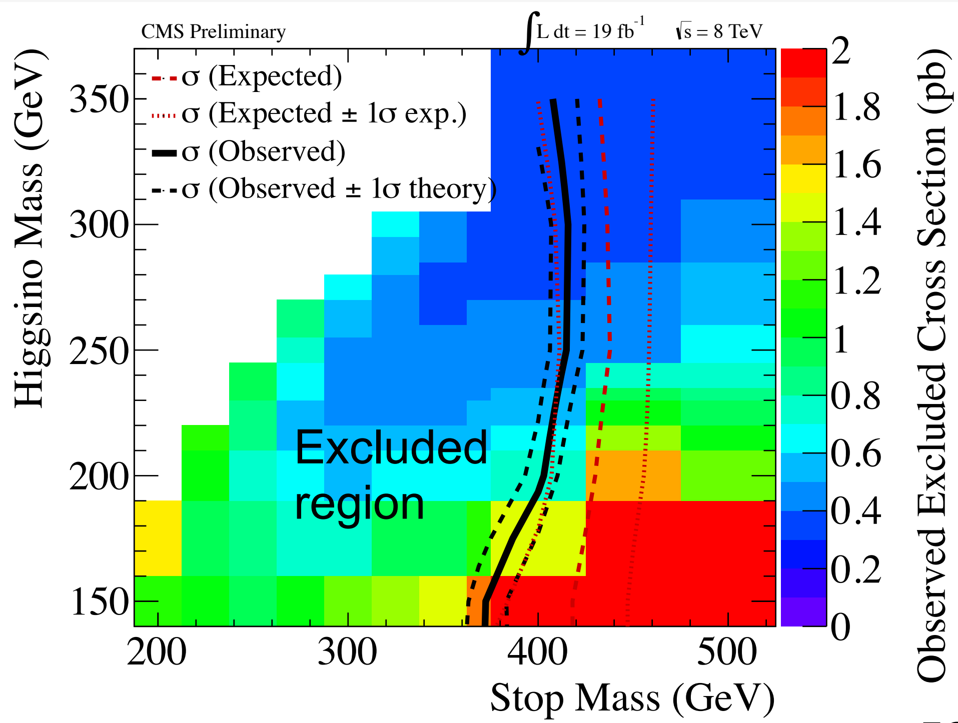
Search for $\tilde{t}$ and $\tilde{\chi}^0$ in H→$\gamma\gamma$ final states

SUS-13-014 https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS13014

Parallel talk: David Morse

- Selection: 2 photons (isolated, ET>40, 25 GeV), ≥2 b-jets (pT>30 GeV).
- Use H→$\gamma\gamma$ mass sidebands to predict background MET distrib.
- Normalize to number of events obtained from fit to M($\gamma\gamma$).
- 3 samples: 2 b-jets with M(bb)~M(H); ≥3 b-jets; other.





MC signals peak at high MET

Outline

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  $\tilde{\chi}_i^0\,,\ \tilde{\chi}_j^{\pm}\ ,\ \tilde{\ell}$
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- Multi-leptons and R-parity violating signatures
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Drawing courtesy Sergio Cittolin

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https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

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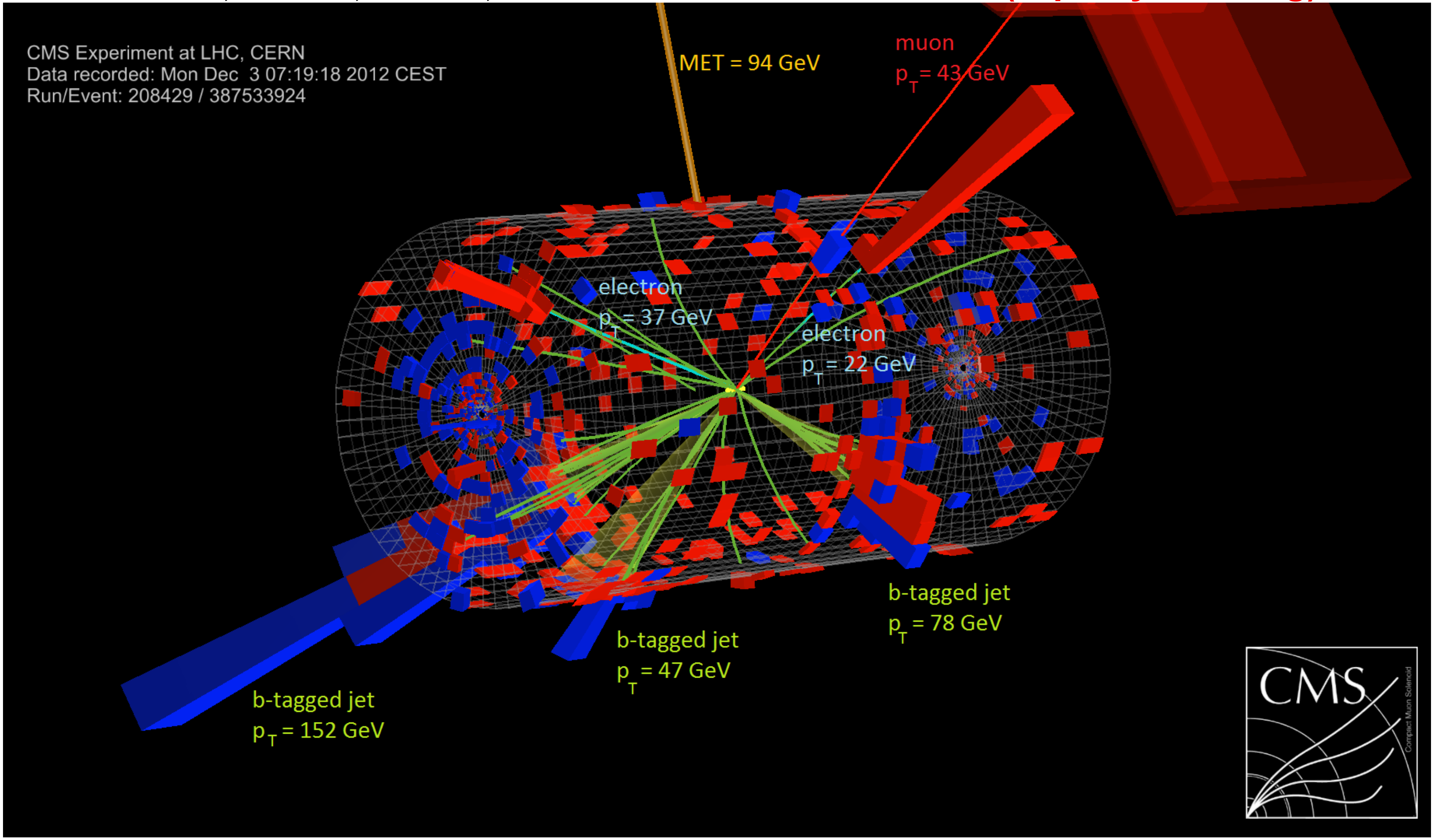
Multi-lepton and R-parity violating processes

SUS-13-002, 13-008 **Andrea Gozzelino (multilepton)**

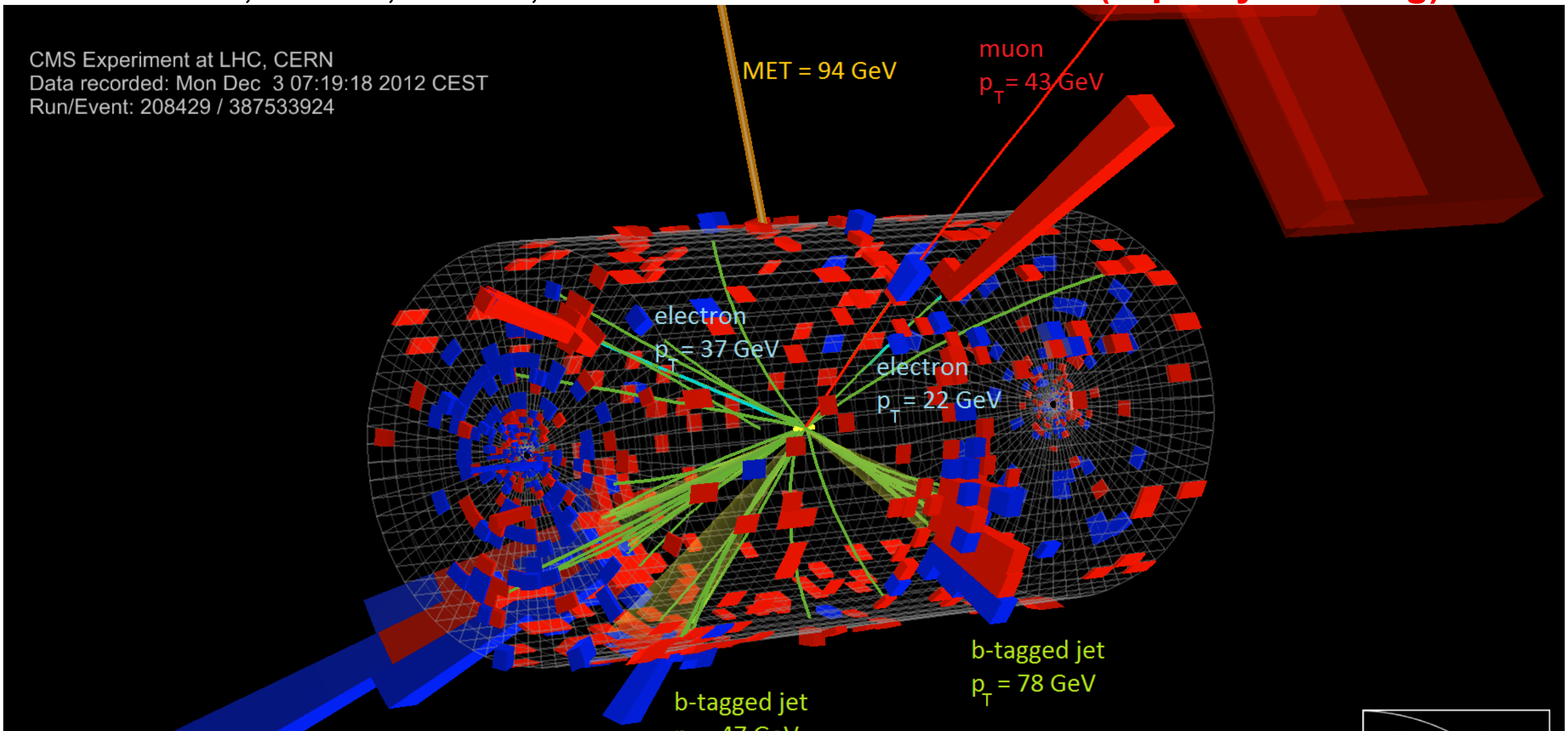
SUS-13-003, 13-010, 13-013, EXO-12-049 **Matthew Walker (R-parity violating)**



Multi-lepton and R-parity violating processes

SUS-13-002, 13-008 **Andrea Gozzelino (multilepton)**

SUS-13-003, 13-010, 13-013, EXO-12-049 **Matthew Walker (R-parity violating)**



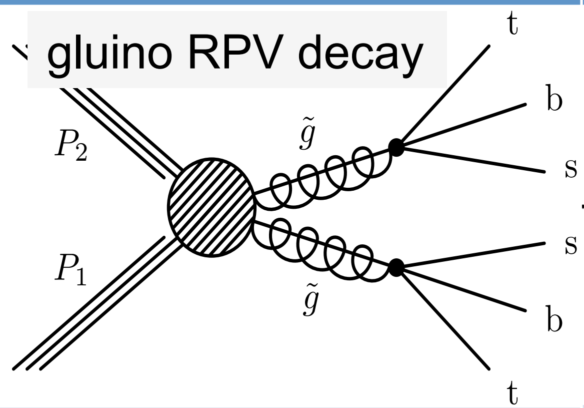
Common theme: powerful signatures that strongly suppress ttbar and other SM backgrounds. Typically have loose/no MET cuts!

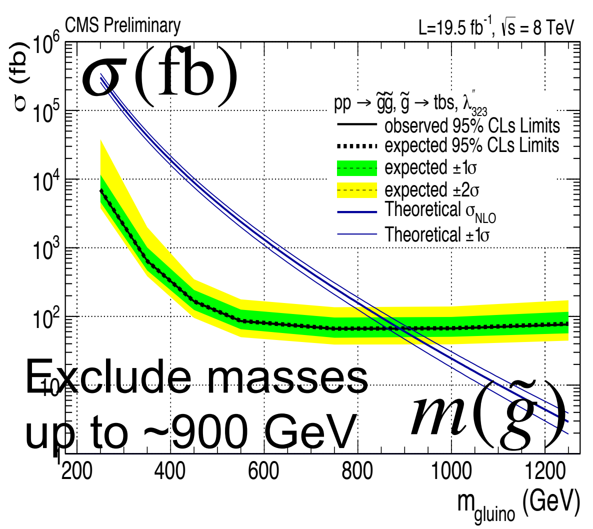
→ **Access to compressed spectra and R-PV SUSY.**

Multilepton searches with R-PV interpretations

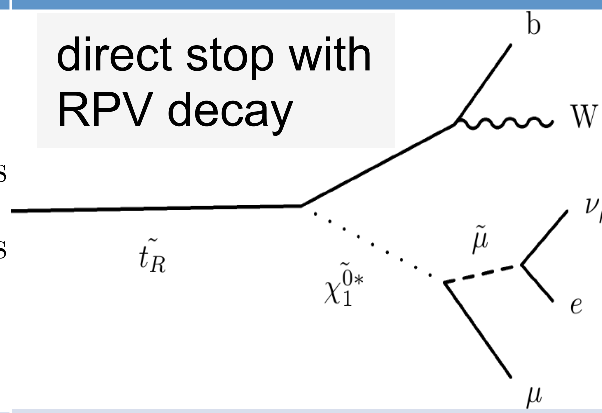
Matthew Walker (R-parity violating)

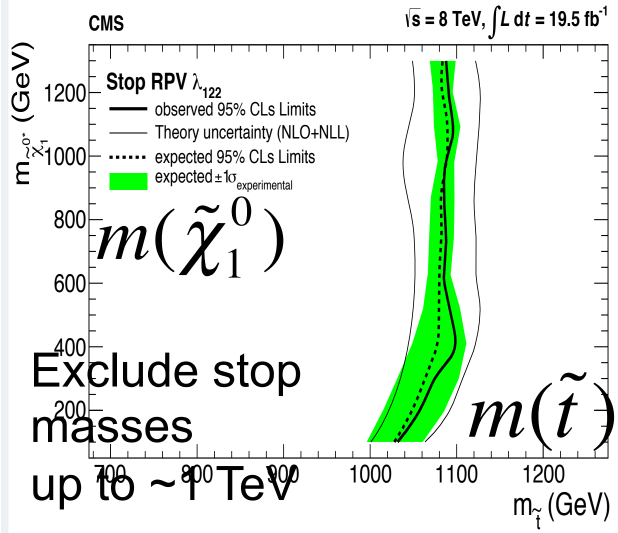
Same-sign dileptons + b-tags (SUS-13-013)



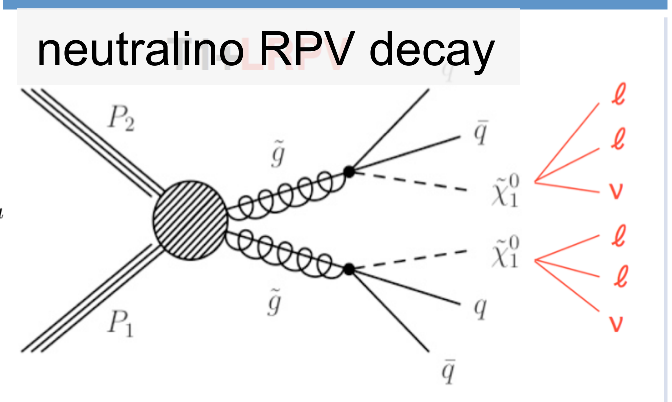


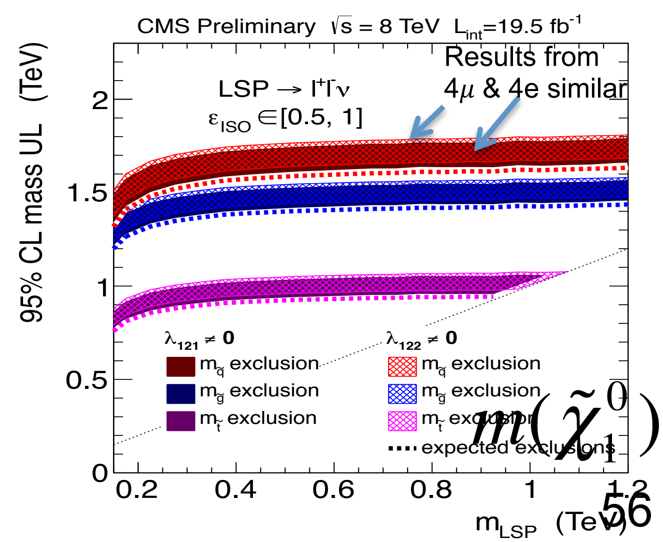
≥3 leptons + b-tags (SUS-13-003)





4 leptons (SUS-13-010)





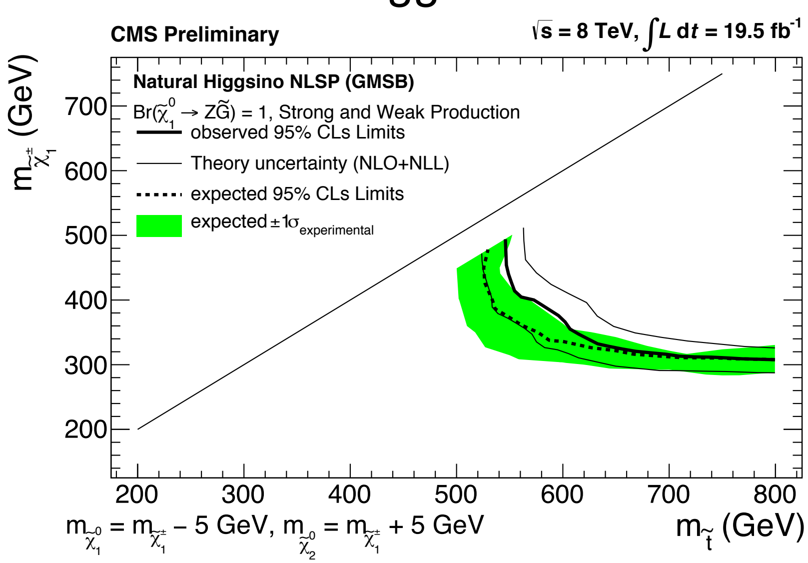
Multilepton searches: general

SUS-13-002

Search for anomalous lepton production

- ≥3 leptons (e, μ, τ)
- Binning in N(lep), N(τ), N(b-jet)=0, ≥1, MET, HT, OSSF pairs, on Z/off Z

GMSB natural higgsino NLSP scenario



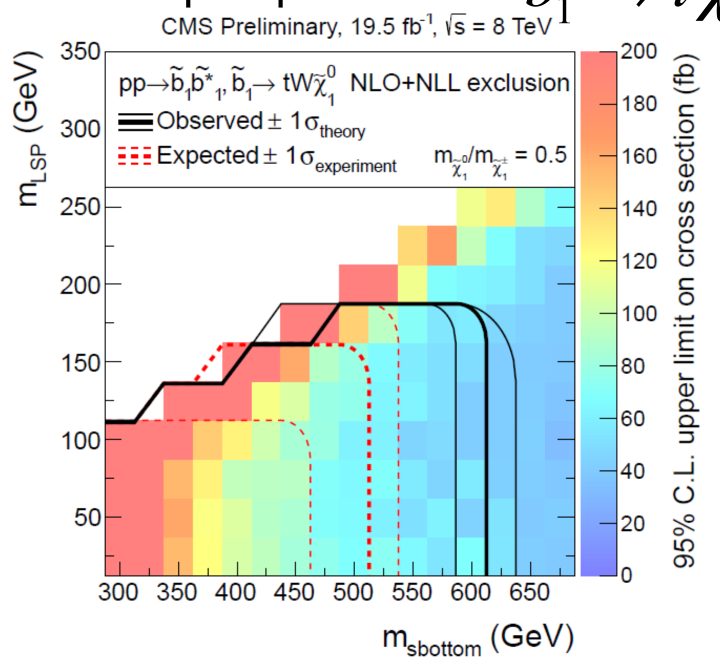
SUS-13-008

Andrea Gozzelino talk

Search for events with ≥3 leptons, ≥2 jet, ≥1 b-jet.

- 3(e, μ)
- Binning in
- N(lep), N(jets), N(b-jets), MET, HT, on Z/off Z

Sbottom pair production $\tilde{b}_1 \rightarrow t\tilde{\chi}_1^-$



Conclusions

- Over the first 3 years of LHC running, we have developed a broad SUSY program, with an extensive set of searches.
- There is no evidence for a signal in any search.
- The overall behavior of SM backgrounds in the data sample appears to be well understood.
- Searches for gluinos and squarks are highly developed.
- There is significant progress in developing searches for EWKinos.
- Compressed spectra represent a challenge.
- Interpretation is complex; much ongoing work.
- We expect very substantial gains in the discovery reach for the upcoming run.

Backup slides

from Frank Golf talk

Snowmass Projections

- Scale signal and background by cross section ratios ($\sigma_{14\,\mathrm{TeV}}/\sigma_{8\,\mathrm{TeV}}$) and luminosity (300/20 ~ 15).
- Estimate 5σ discovery reach for two scenarios:
  - **Scenario A (conservative)**: Scale background uncertainty by ratio of σ x L.
  - **Scenario B (optimistic)**: Reduced background uncertainty relative to conservative scenario.
- **Caveat emptor**: Projections assume constant performance. We have not attempted any optimization nor accounted for potential degradation due to effects such as increased pile-up.

Process	Decay	Search	Current (TeV)	Scenario A (TeV)	Scenario B (TeV)
$pp \to \tilde{g}\tilde{g}$	$\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$	$\ell + b + \not{E}_T$	1.1 TeV	1.9 TeV	–
	$\tilde{g} \to b\bar{b}\tilde{\chi}_1^0$	$b + \not{E}_T$	1.1 TeV	1.9 TeV	–
$pp \to \tilde{b}\tilde{b}^*$	$\tilde{b} \to t\tilde{\chi}_1^- \to tW^-\tilde{\chi}_1^0$	$\ell^\pm\ell^\pm + b + \not{E}_T$	0.45	0.6	0.75
$pp \to \tilde{t}\tilde{t}^*$	$\tilde{t} \to t\tilde{\chi}_1^0$	$\ell + b + \not{E}_T$	0.25-0.5	0.75	0.95
$pp \to \tilde{\chi}_1^\pm\tilde{\chi}_2^0$	$WZ\tilde{\chi}_1^0\tilde{\chi}_1^0$	$3\ell + \not{E}_T$	0.25	0.45	0.6
	$WH\tilde{\chi}_1^0\tilde{\chi}_1^0$	$\ell + b + \not{E}_T$	0.2	0.4	>0.5

from Frank Golf talk

Stop Projection

Significance = $\frac{N_{sig}}{\sqrt{N_{bkgd} + \sigma^2_{bkgd}}}$

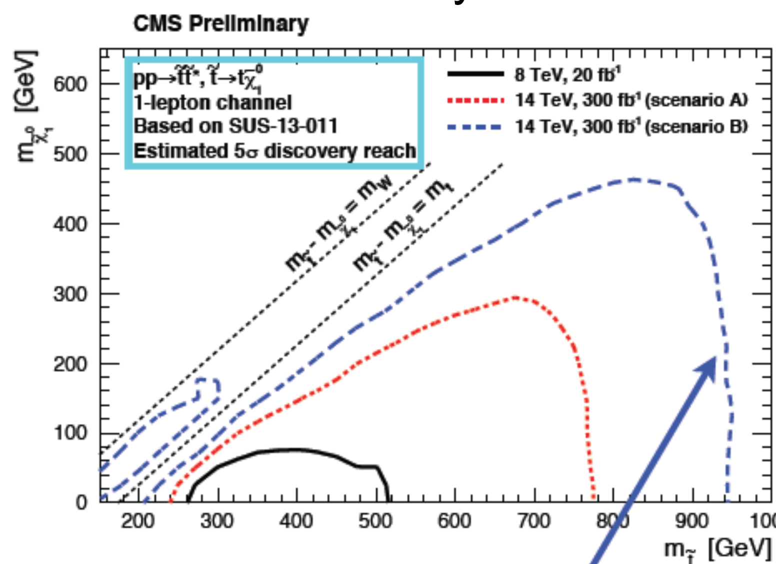
Bkgd scaling: $R_{bkgd} = \left(\frac{300\ \mathrm{fb}^{-1}}{20\ \mathrm{fb}^{-1}}\right) \times \boxed{\frac{\sigma_{t\bar{t}}(14\ \mathrm{TeV})}{\sigma_{t\bar{t}}(8\ \mathrm{TeV})}}$

$= 15 \times \left(\frac{965\ \mathrm{fb}}{249\ \mathrm{fb}} \sim 3.9\right) = 60$

Signal scaling: $R_{sig} = \left(\frac{300\ \mathrm{fb}^{-1}}{20\ \mathrm{fb}^{-1}}\right) \times \boxed{\frac{\sigma_{\tilde{t}\tilde{t}^*}(14\ \mathrm{TeV})}{\sigma_{\tilde{t}\tilde{t}^*}(8\ \mathrm{TeV})}}$

$= 15 \times$ (~4-20 for M_{stop} of 0.2-1 TeV) = 60-300

5σ discovery curves

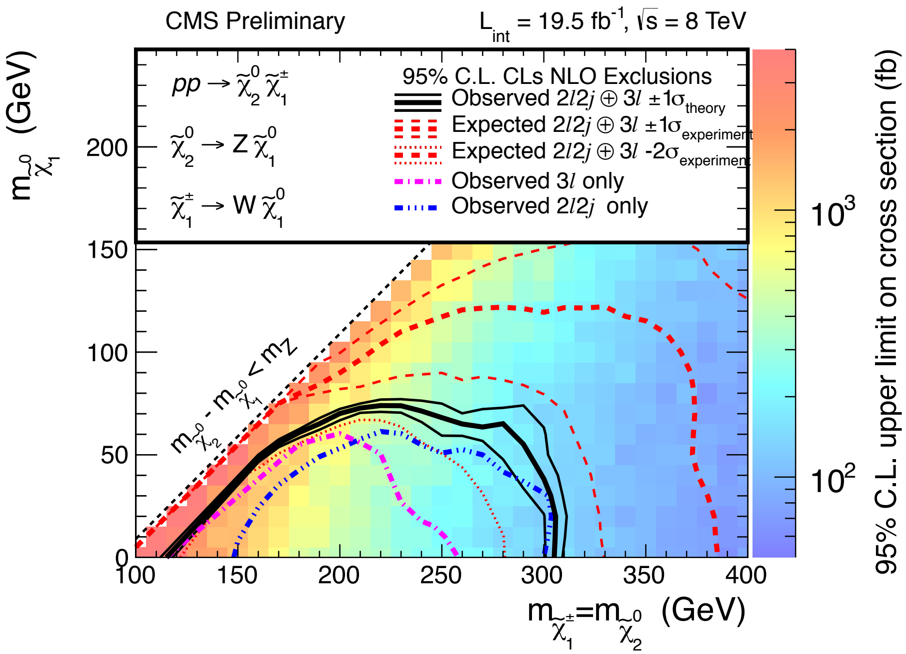


Reduce background uncertainty by $\sqrt{R_{bkgd}}$ relative to Scenario A.

Electroweak production: $\tilde{\chi}_i^0, \tilde{\chi}_j^\pm, \tilde{\ell}$

SUS-13-006 https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS13006

WZ+MET: search complementarity



Slepton exclusion region