SUSY Searches with Jets and Missing Transverse Momentum: Lost Lepton Background and Results with 12.9/fb Data

CORFU2016: Summer School and Workshop on the Standard Model and Beyond

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DER FORSCHUNG | DER LEHRE | DER BILDUNG

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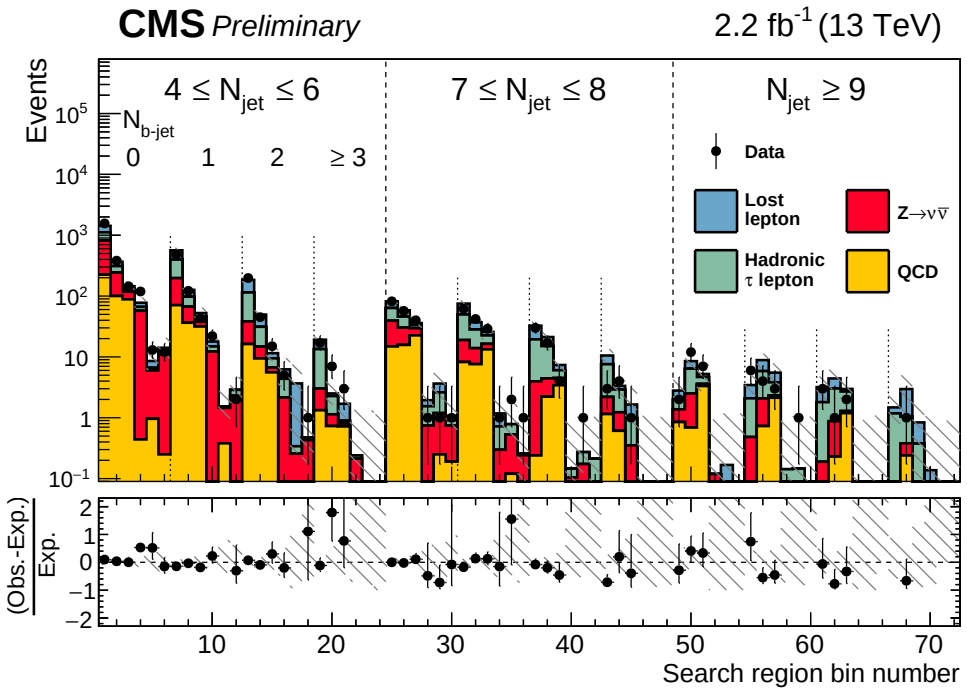
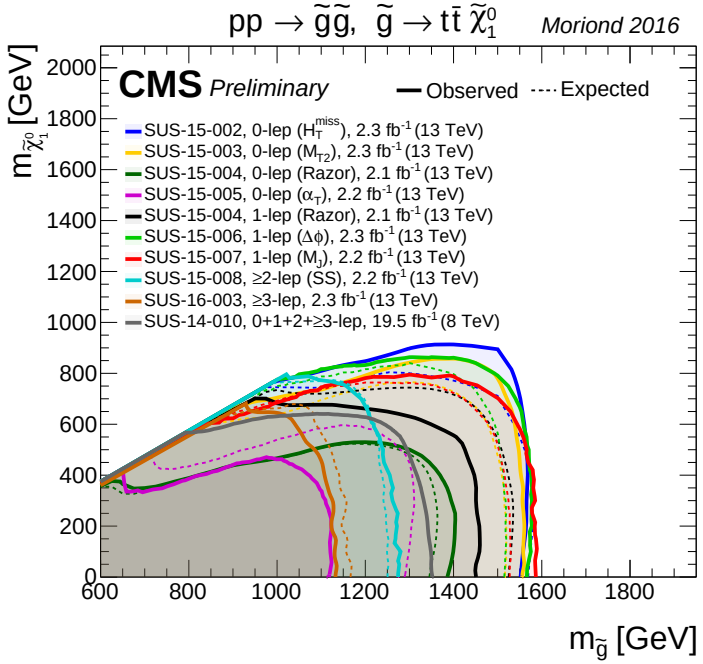
- RA2/b: Search for Supersymmetry
  - First CMS SUSY analysis to get approved for Moriond 2016
  - Published paper this year (again first...): doi:10.1016/j.physletb.2016.05.002
  - Search in 72 search bins (we'll get there)
  - No sign of SUSY :(



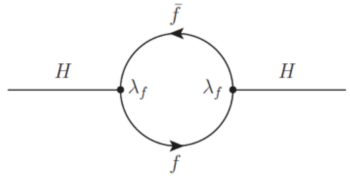


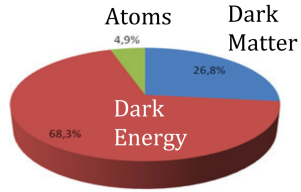
SUSY Propaganda

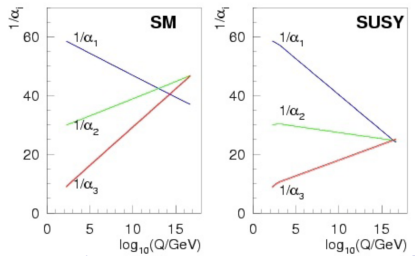
Nice features of Supersymmetry:

- Solving hierarchy problem without 'fine tuning'
- Provides Dark Matter candidate
- Unification of gauge couplings
- ...

→ Some arguments most convincing for SUSY at TeV scale

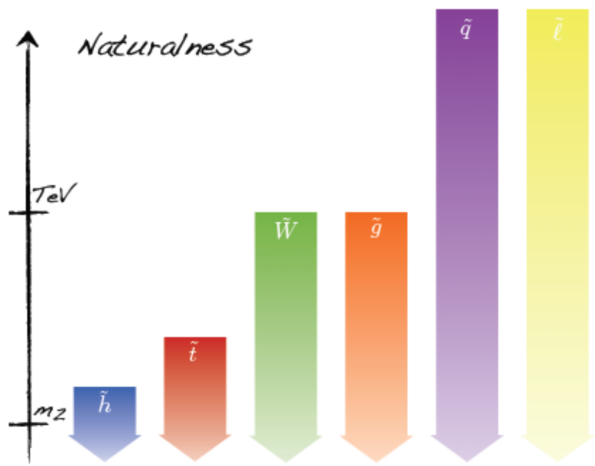






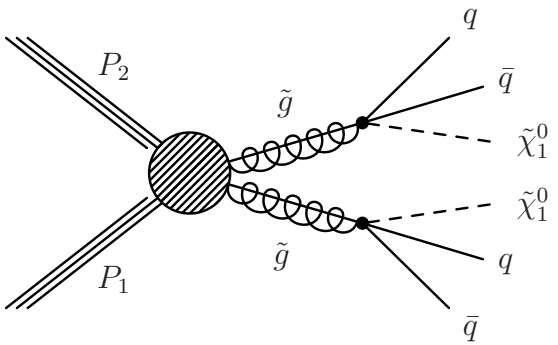
Natural SUSY:

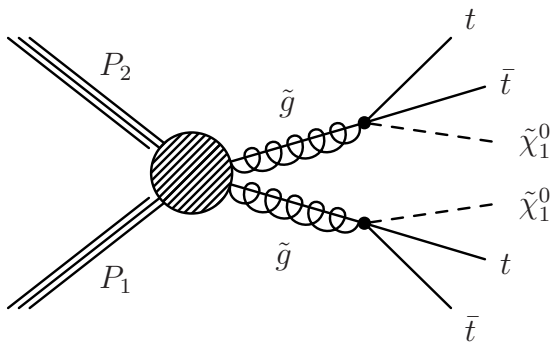
- Require no large cancellations:
  - Tree level: light higgsinos
  - 1-loop: light stops and winos
  - 2-loop: light gluinos
- SUSY mass scales motivated by electroweak naturalness
  → 'allowed' level of fine tuning is a matter of taste

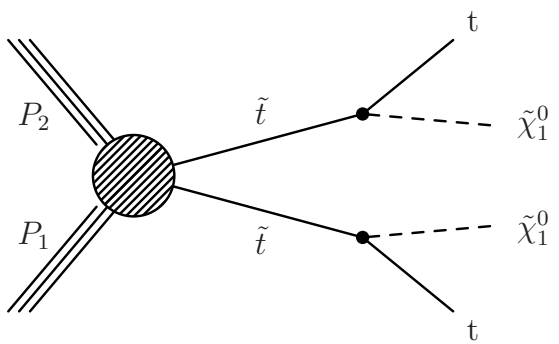


RA2/b: Event Selection I

- Search for supersymmetry in the all-hadronic final state targeting gluino and stop pair production
  - Motivated by naturalness and high cross section







Event selection I

- Transverse momentum:

  $H_T = \sum |p_T| > 300\,\mathrm{GeV} \quad (H_T\text{-jets: } p_T > 30\,\mathrm{GeV}, |\eta| < 2.5)$

- Jet multiplicity:

  $N_{\mathrm{Jets}} = \#\ (H_T\text{-Jets}) \geq 3$

- Missing transverse momentum:

  $H_T^{\mathrm{miss}} = |-\sum \vec{p_T}| > 300\,\mathrm{GeV} \quad (H_T^{\mathrm{miss}}\text{-jets: } p_T > 30\,\mathrm{GeV}, |\eta| < 5)$

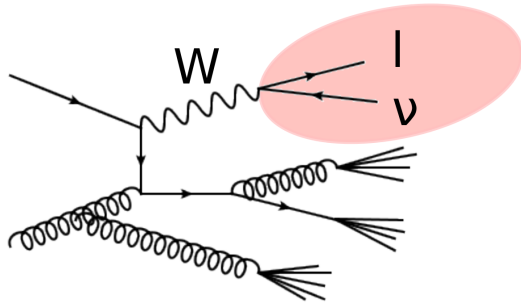
- Veto on e, μ

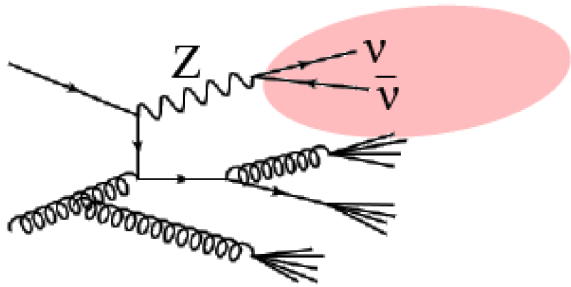
$\Rightarrow$ **Search in 160 exclusive search bins defined by H_T, H_T^{miss}, N_{Jets}, N_{BTags}**

- Introduce additional selection cuts in order to suppress Standard Model background events

Event selection II

- QCD: heavily mismeasured jet
  - $\Delta\Phi(H_T^{\text{miss}}, Jet_{\{1,2,3,4\}}) > \{0.5, 0.5, 0.3, 0.3\}$
- W + jets, $t\bar{t}$: lost electron, muon (+neutrino)
  - Lepton veto: e, μ ($p_T > 10\,\text{GeV}, |\eta| < 2.4/2.5$)
  - Isolated tracks veto: e, μ ($p_T > 5\,\text{GeV}$)
- W + jets, $t\bar{t}$: hadronically decaying tau (+neutrino)
  - Isolated tracks veto: π ($p_T > 10\,\text{GeV}$)
- $Z \to \nu\nu$ + jets
  - Irreducible





Extreme region of phasespace requires data-driven prediction

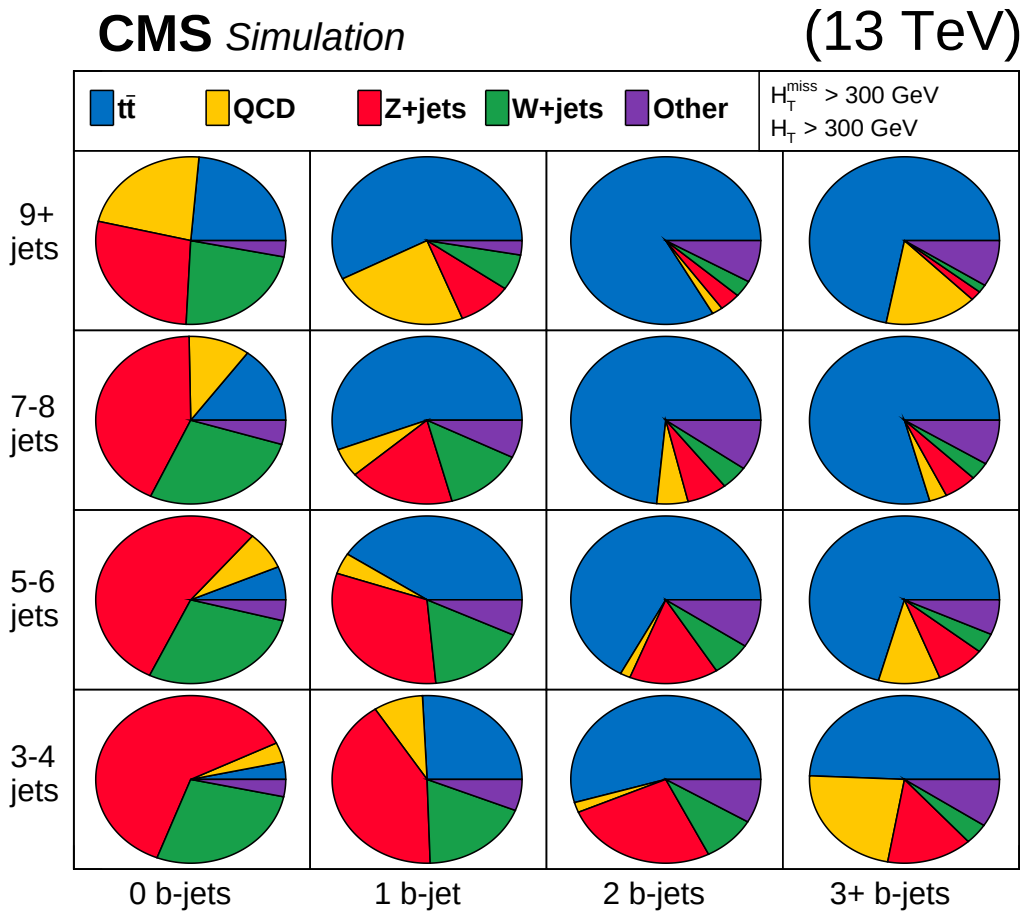


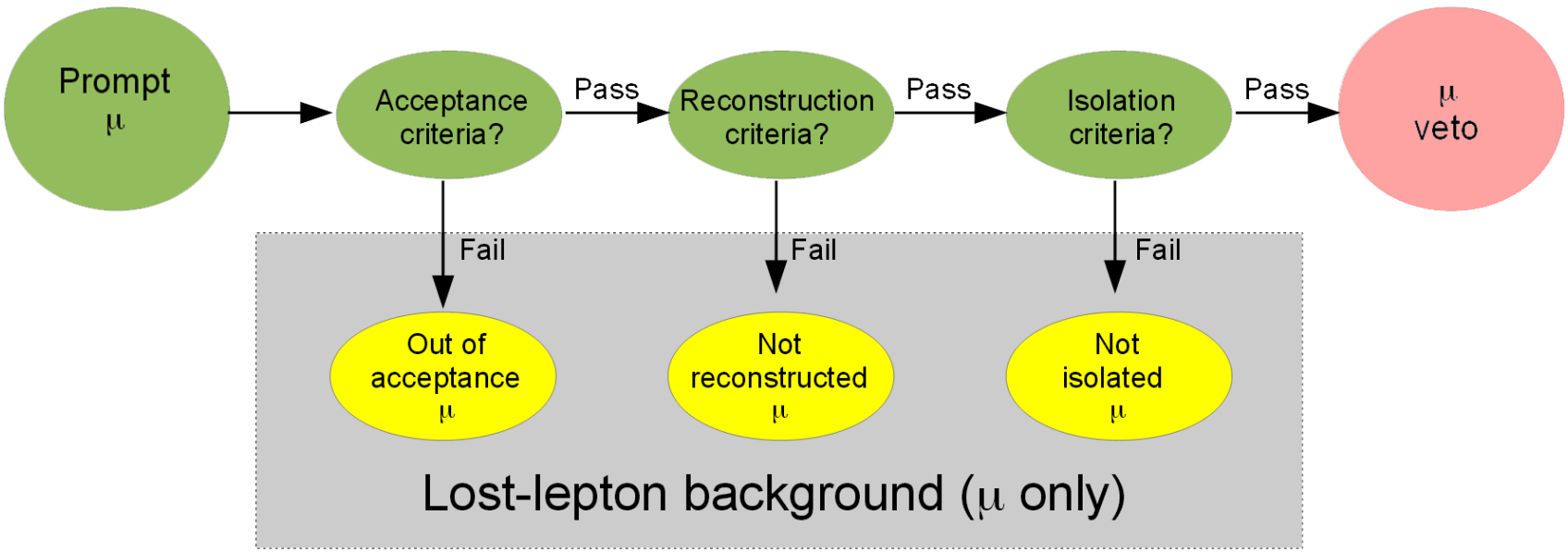
Figure: J. Bradmiller-Feld, UCSB

Lost-Lepton: important background in most sensitive search bins

Lost-Lepton Background

Origin of Lost-Lepton Background

- Events are vetoed if an isolated lepton is found...
- ...but the lepton might also be 'lost' [equivalent for electrons]



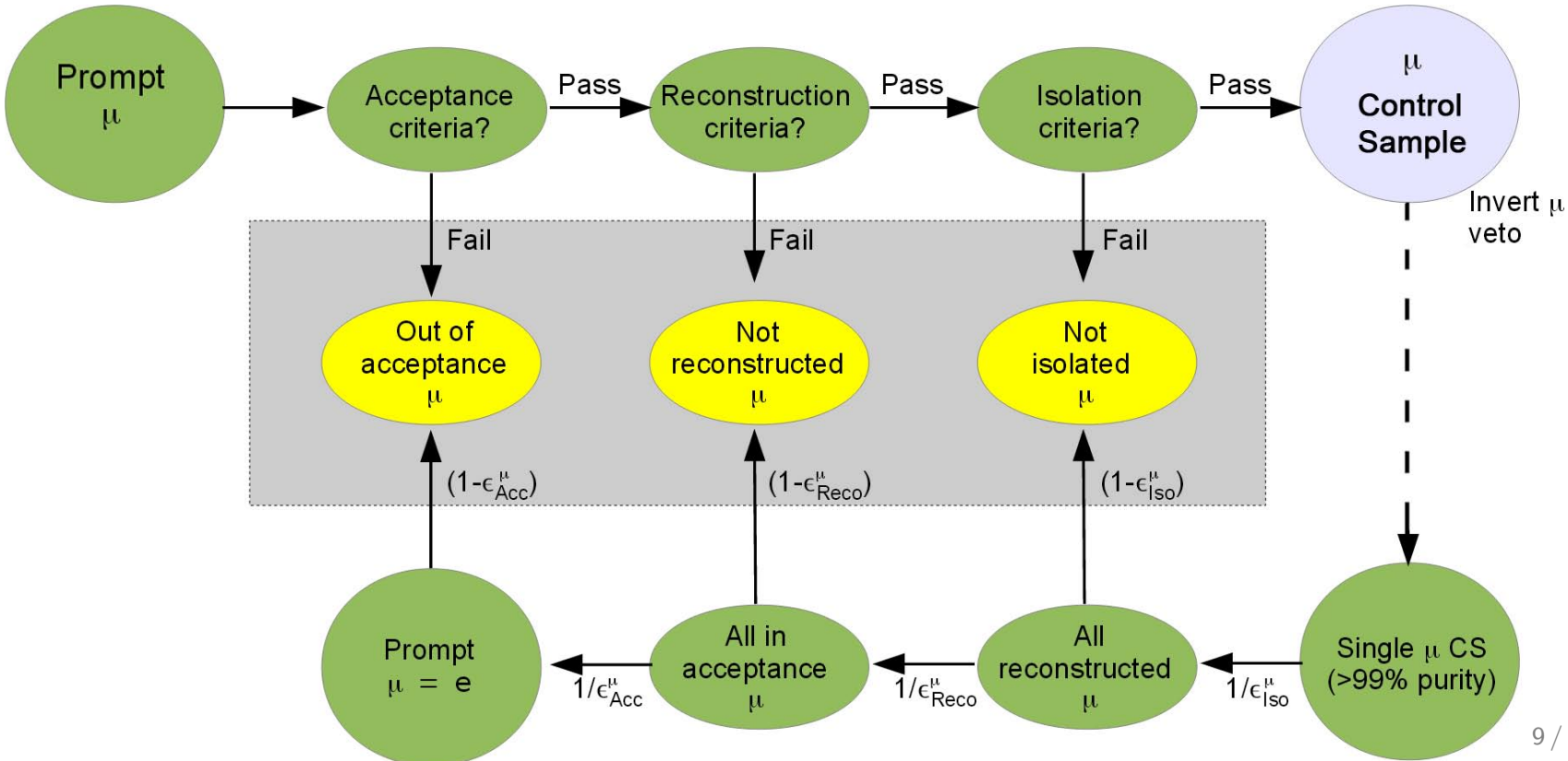
Prediction of Lost-Lepton Background I

- Idea: Start from the end of the chain (single lepton control sample) and retrace in which step how many leptons have passed/failed each of the criteria

- Example: We observed 18 isolated muons. We know that about 90% of the reconstructed muons are isolated.

$\rightarrow N_{\mu}^{\text{non-isolated}} = N_{\mu}^{\text{isolated}} \cdot \frac{1-\epsilon_{\text{Iso}}}{\epsilon_{\text{Iso}}} = 18 \cdot \frac{1-0.9}{0.9} = 2$

- In fact, it's not that simple:

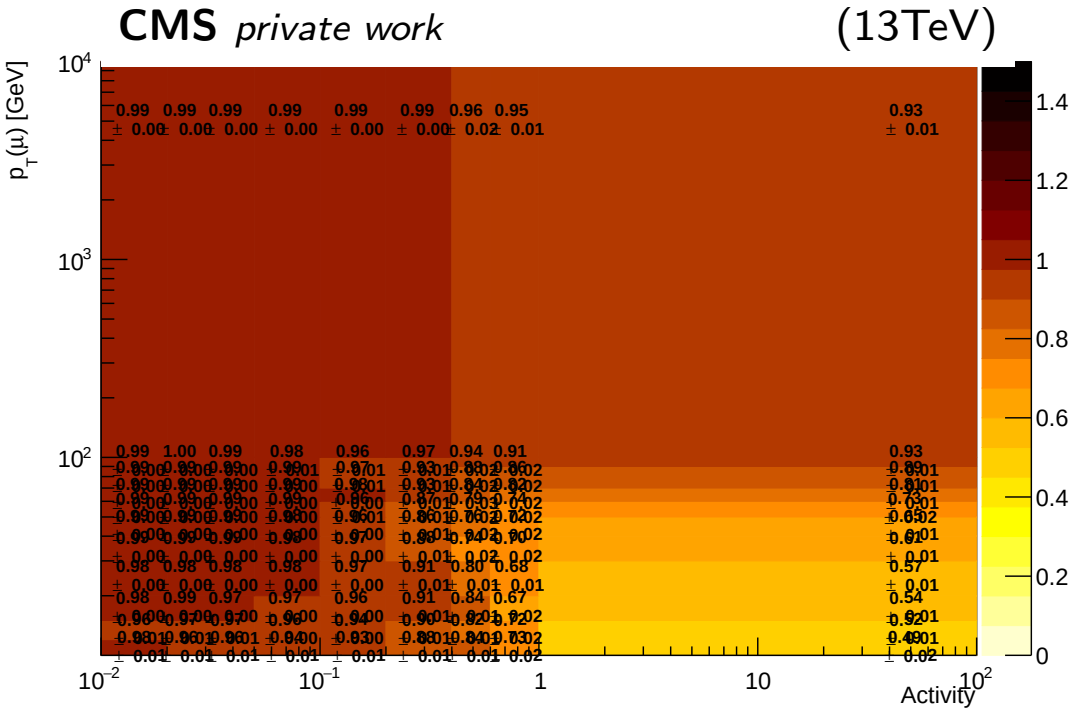


Prediction of Lost-Lepton Background II

- Each of the (in-) efficiencies is a complicated function of various parameters
- Goal: Find a set of 2-3 suited observables to parametrize each efficiency
  - Should reflect event kinematics...
  - ...but also don't vary too much (problematic for low stat. search bins)

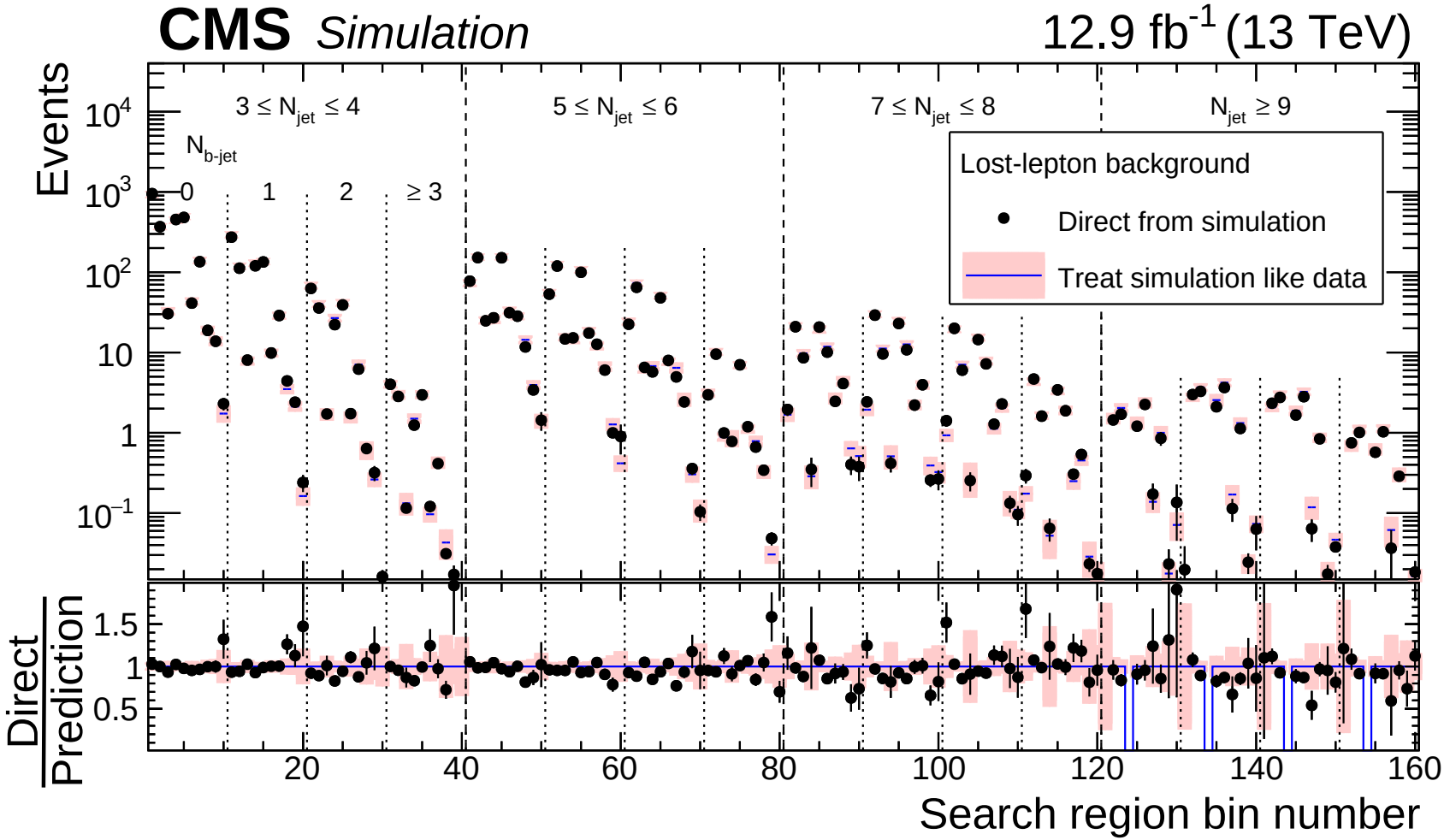
- Example muon isolation: p_T and *activity* around a lepton

$$act. := \left(\sum_{\text{PFcands}}^{R_{\text{miniIso}} < r < 0.4} p_T \right) / p_T(lep)$$



Prediction of Lost-Lepton Background IV

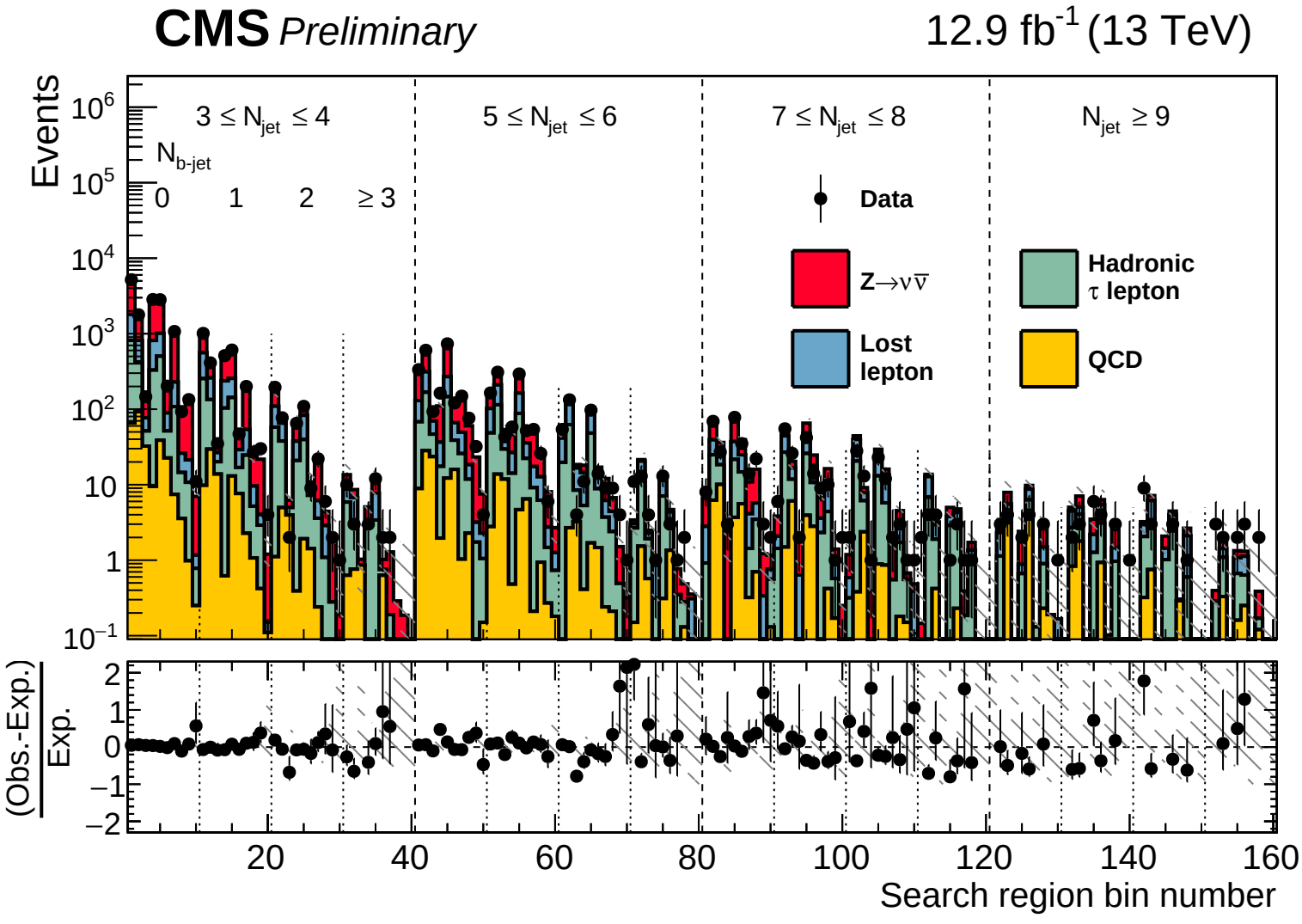
- Closure test for all 160 search bins: overall very good agreement
  - Average prediction from e and μ CS



Successful data-driven prediction of lost-lepton background!

Results

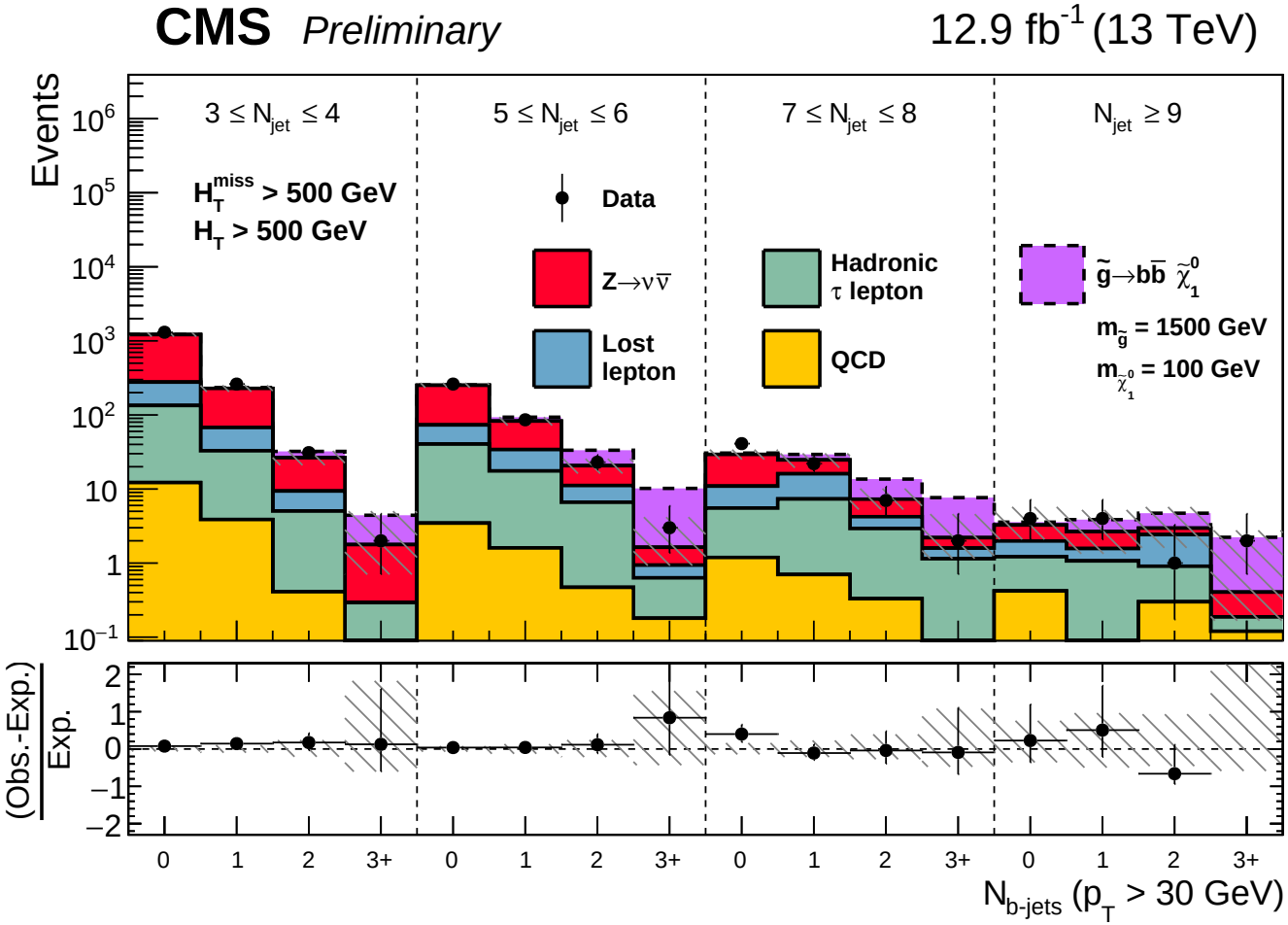
- Approved results for all 160 search bins using $12.9\,\mathrm{fb}^{-1}$ of data
  - Observed data in good agreement with the SM background prediction



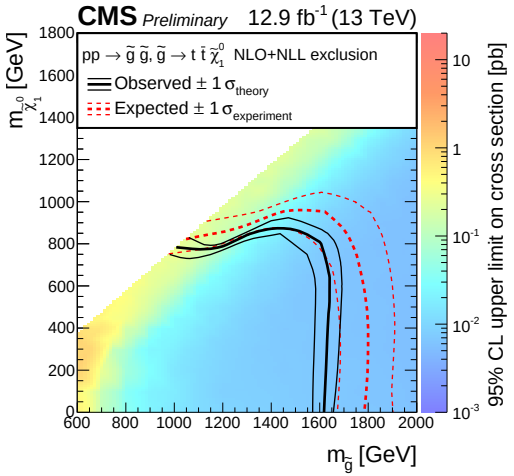
No sign of SUSY!

Integrating over H_T and H_T^{miss}

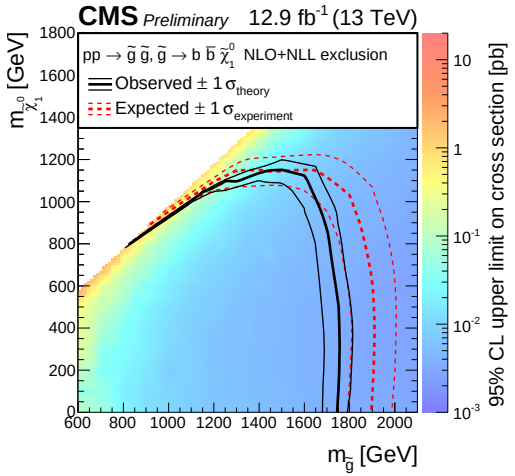
- 2D projection ($H_T, H_T^{\text{miss}} > 500\,\text{GeV}$), overlain with signal (T1bbbb)
  - Small excess of data in tightest bin
  - Still consistent with background prediction within uncertainties



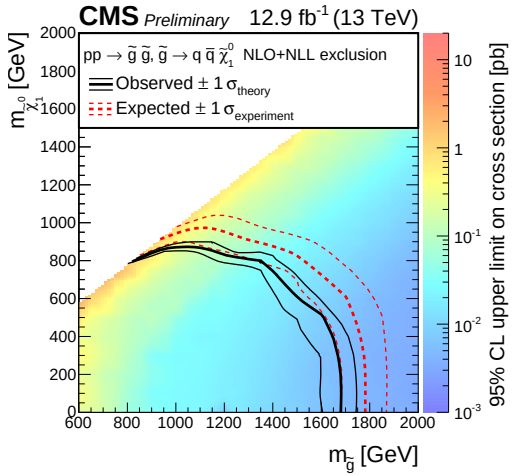
Exclusion Limits



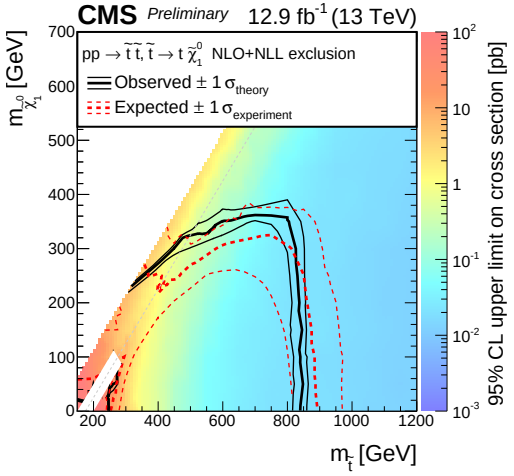
(a) $pp \to \tilde{g}\tilde{g}, \quad \tilde{g} \to t\bar{t}\bar{\chi}_1^0$



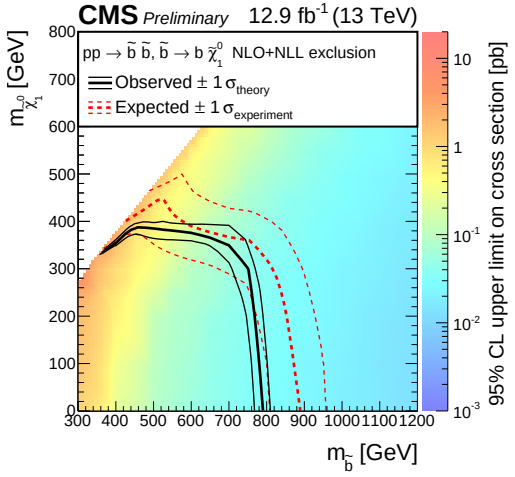
(b) $pp \to \tilde{g}\tilde{g}, \quad \tilde{g} \to b\bar{b}\bar{\chi}_1^0$



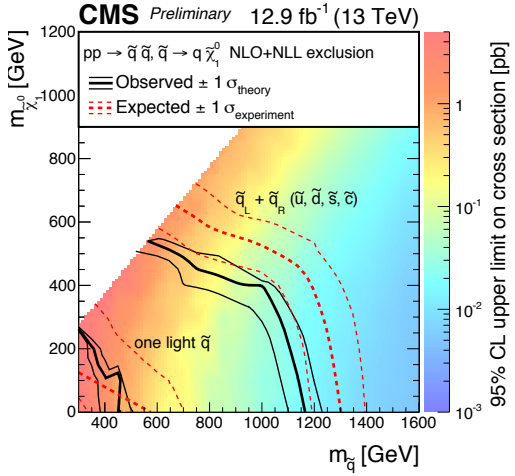
(c) $pp \to \tilde{g}\tilde{g}, \quad \tilde{g} \to q\bar{q}\bar{\chi}_1^0$



(d) $pp \to \tilde{t}\tilde{t}, \quad \tilde{t} \to t\bar{\chi}_1^0$



(e) $pp \to \tilde{b}\tilde{b}, \quad \tilde{b} \to b\bar{\chi}_1^0$



(f) $pp \to \tilde{q}\tilde{q}, \quad \tilde{q} \to q\bar{\chi}_1^0$

Conclusion

- SUSY models with light gluinos/stops decaying to (heavy) quarks highly motivated
  - We expect high values of N_{Jets}, H_T^{miss}
- Extreme phase space requires data-driven estimates of backgrounds
  - Prediction of lost-lepton background shows great performance
- Results of search in $12.9\,\text{fb}^{-1}$ of data presented at ICHEP
  - No sign of SUSY observed
  - Set exclusion limits for 7 different SMS topologies
- It was a great pleasure to carry out the analysis with the RA2/b group once again!
  - Turned the crank within $\mathcal{O}(\text{week})$

Let's hope SUSY is still hiding!

Backup

Signal Sensitivity