

CMS SUSY Searches: Status and Future

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Outline

1. Brief overview of recent CMS SUSY searches
2. Highlight selected new and novel results
3. Challenges → serve as talking points for discussion
 - Stops
 - direct stops challenging
 - Compressed spectra/ISR region
 - “Parked” data
 - Monte Carlo
4. What are we missing?
5. Discussion

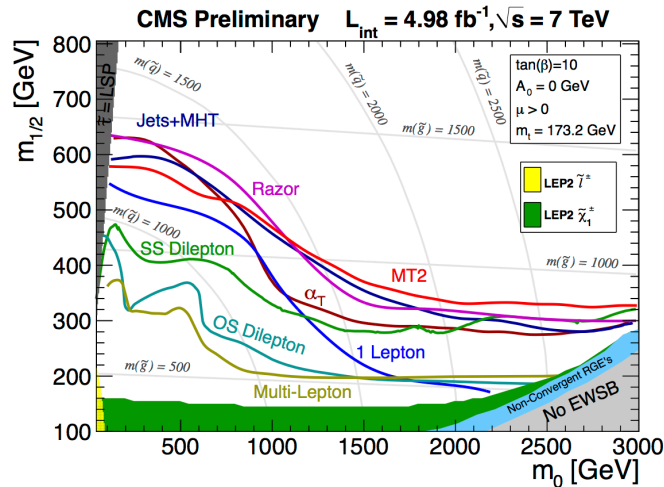
Overview of CMS SUSY Searches

- Inclusive searches
- 3rd generation searches
 - Gluino mediated
 - Direct stop/sbottom
- GMSB
 - photons, taus
- EWK production
- R-parity violation
- Alternative models
 - e.g. Stealth SUSY

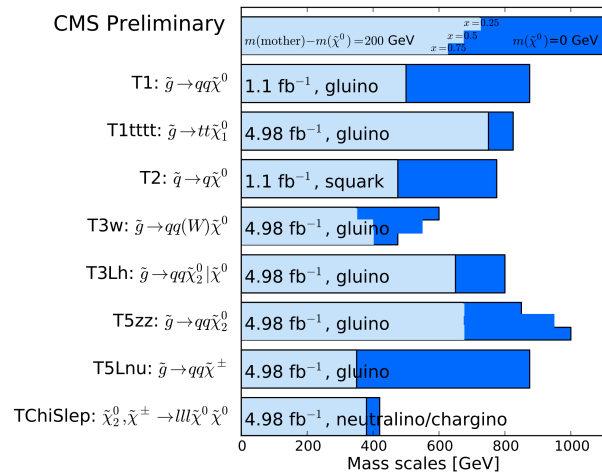
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Inclusive SUSY Searches



- A number of channels and methods pursued
- Analyses focus on simple signatures
 - Common to wide variety of models
- Our results have been most commonly presented in the CMSSM m_0 vs $m_{1/2}$ plane
 - Shows breadth of analyses and large gain in coverage
- Results also interpreted in terms of Simplified Model Spectra (SMS)
 - Fully quantify experimental results
 - e.g. provide reinterpreted limits as well as signal efficiencies vs. mass for benchmark models based on topological signatures



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Third Generation Searches

- Two general types of searches

Some gluino cascade examples

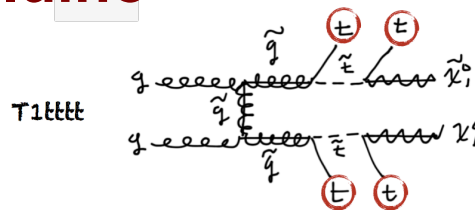
- Production via gluino cascades** e.g.:

- $g \rightarrow b + \text{sbottom}$
- $g \rightarrow t + \text{stop}$
- $g \rightarrow \text{tau tau}$

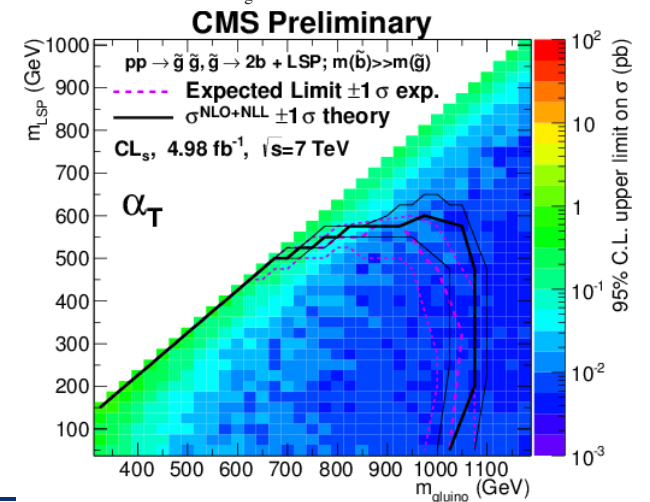
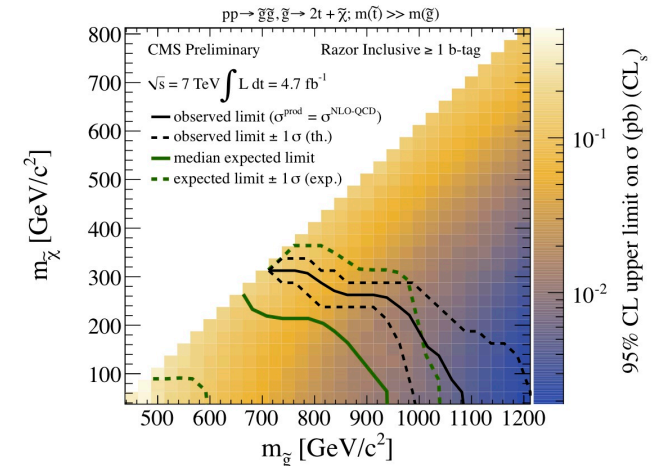
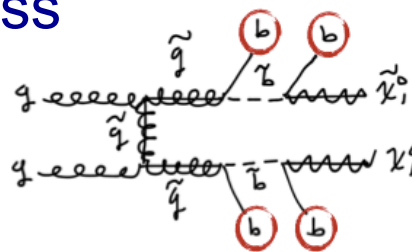
Probed gluino masses
up to about 1 TeV for
 \approx any stop/sbottom mass

- Direct production**

- Next page...

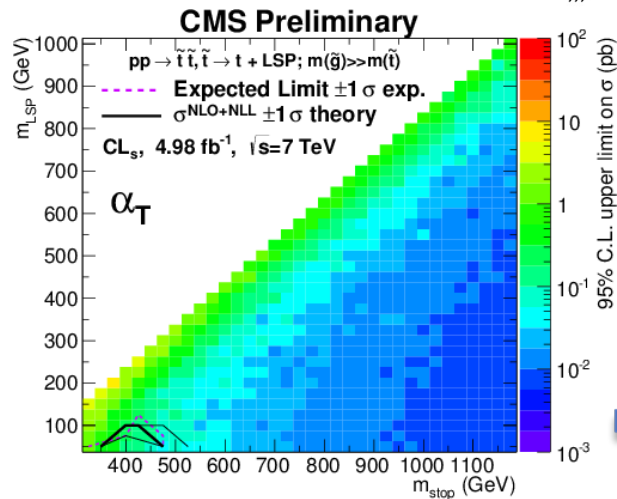
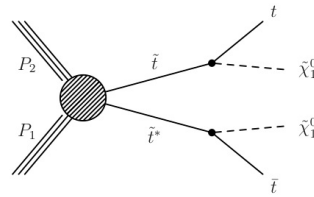
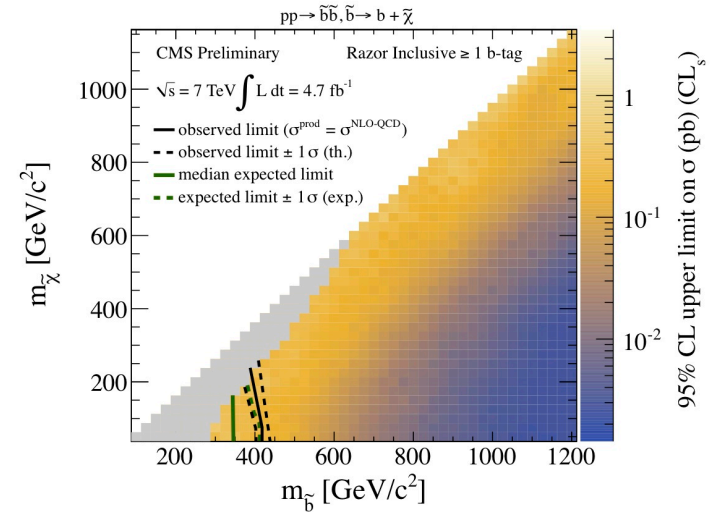
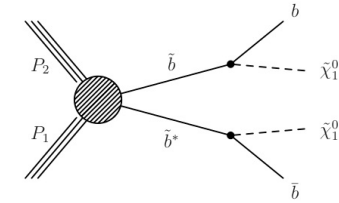


$\tau 1 b b b b$

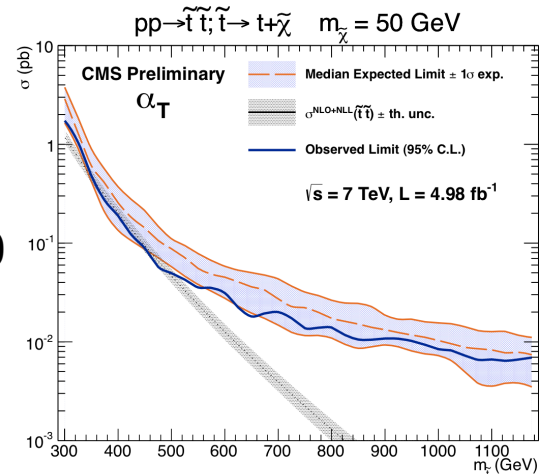


Direct stop/sbottom Production

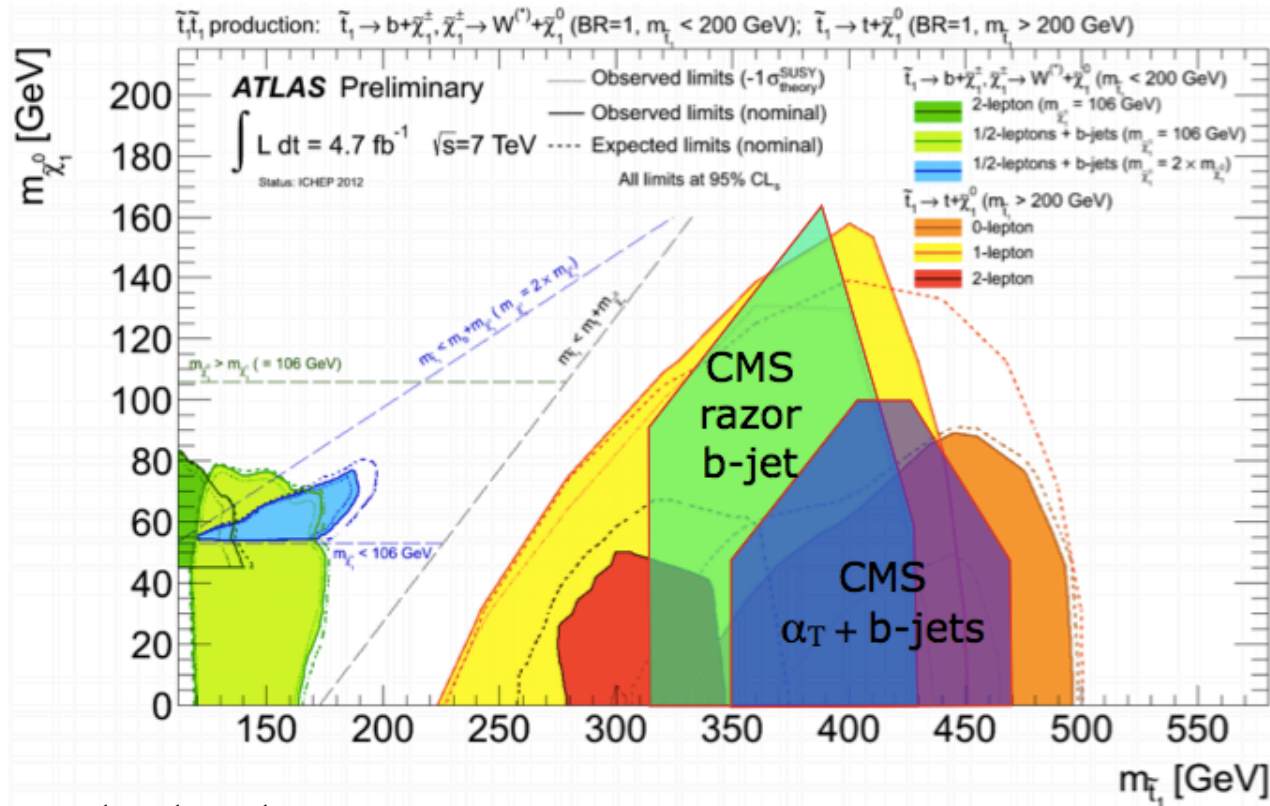
- Inclusive searches have sensitivity
 - Examples shown
- Targeted searches are ongoing and challenging
 - More on this later



mLSP=50
GeV slice



CMS-ATLAS Comparison



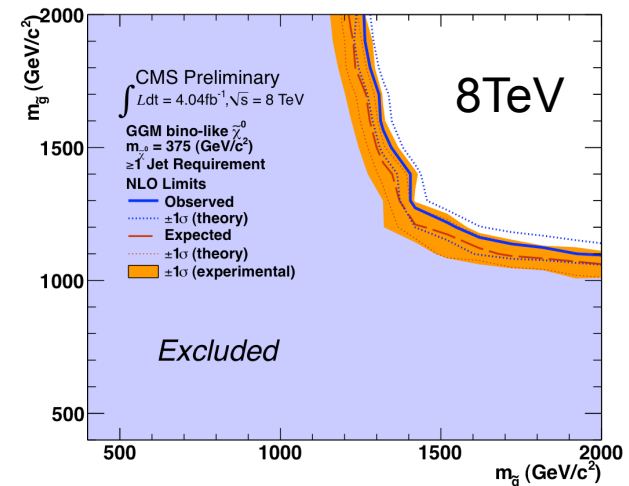
Daniele Alves
 “Implications”
 workshop
 @CERN

Important notes:

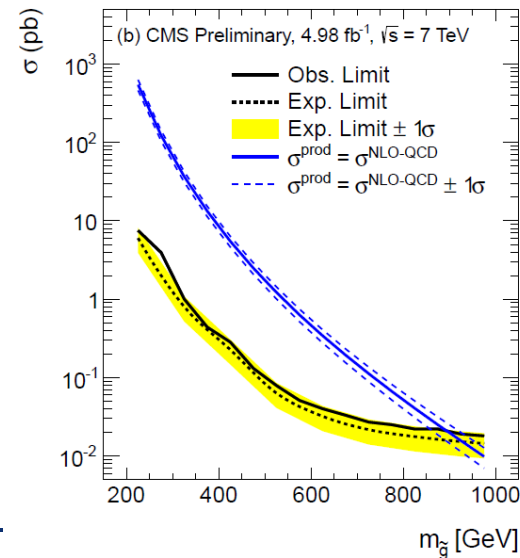
- 1) Region near diagonal removed due to uncertainties in ISR modeling.
 - 2) Limited granularity in our signal scans.
- For 8TeV we are preparing finer scans; production is a computing challenge.

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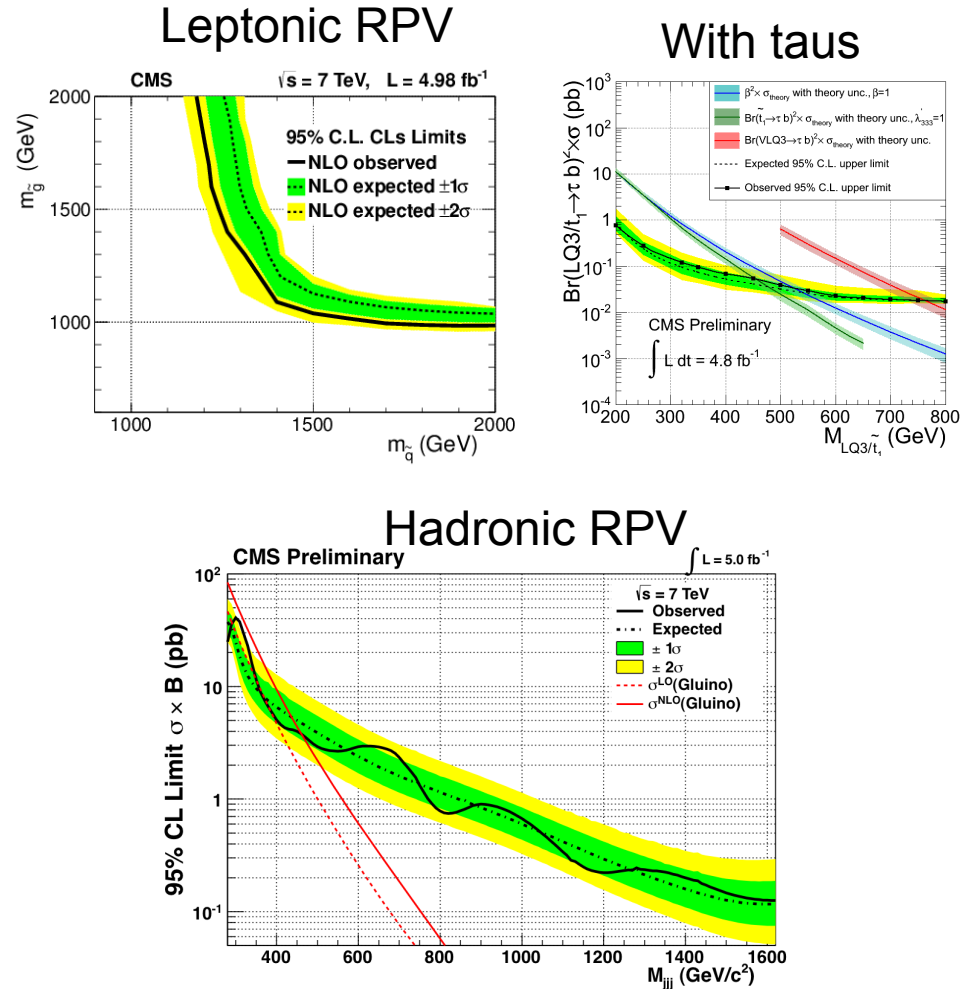
$\gamma\gamma$



$\tau\tau$

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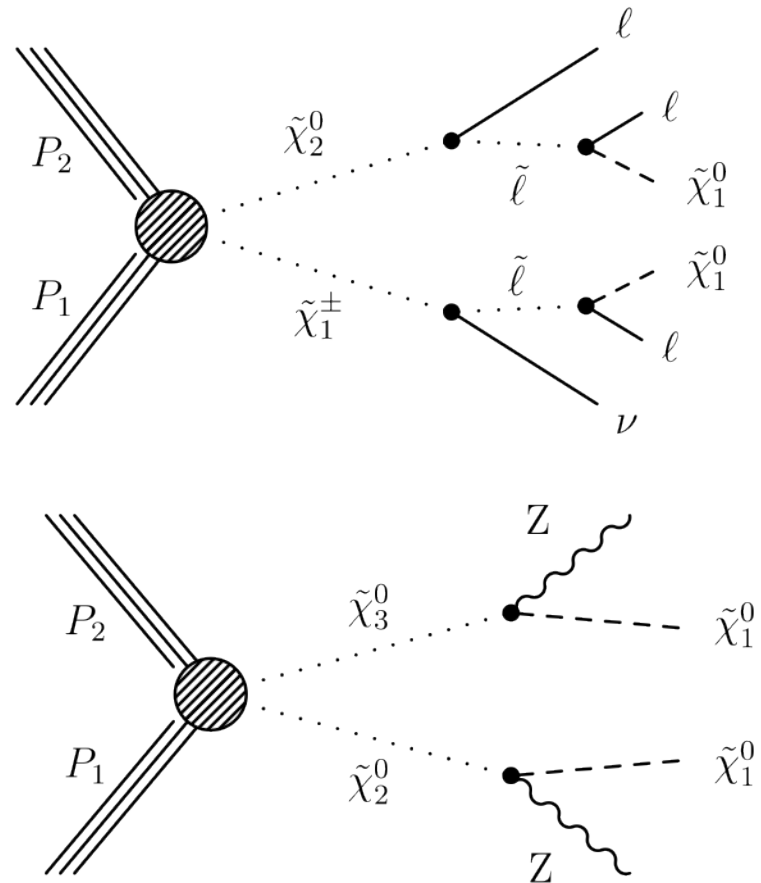
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Will now highlight a couple of selected new and novel searches

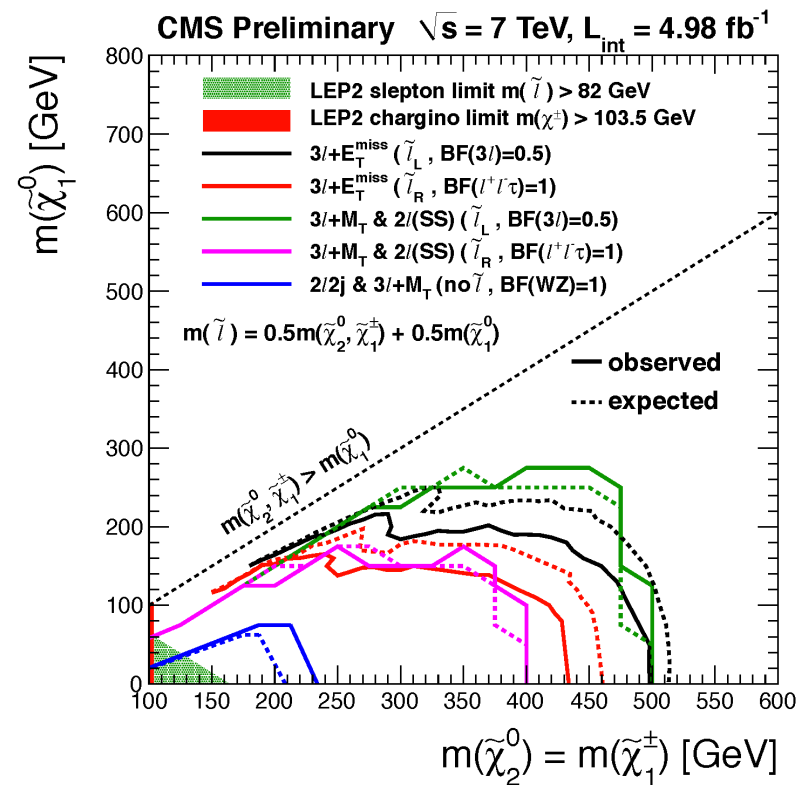
What's new?: EWK Production

- **New search for chargino-neutralino production**
 - Hot-off-the-press (approved and soon to be public)
 - A preview of what is to be unveiled at SUSY12
- **Experimental signatures:**
 - $4l$, $3l + \text{MET}$, $3l + M(\text{ll}) + M_T$, $2l$ (same-sign), $Z(\text{ll})V(\text{jj})$
 - Includes reinterpretation of arXiv/1204.5341
 - As well as targeted complementary searches
- **Investigate two classes of models**
 - With and without light sleptons
 - Examples on the right



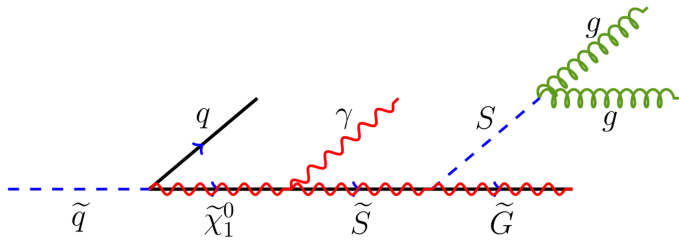
EWK Production

- **Interpretations** (summary on right)
 - $\chi^+\chi^0$ SMS with slepton-mediated decays
 - $3l + \text{MET}$
 - $3l + M(\text{ll}) + M_T$
 - $2l(\text{SS})$
 - $\chi^+\chi^0$ SMS with decays to $W/Z + \text{LSP}$
 - $3l + M(\text{ll}) + M_T$
 - $Z(\text{ll})V(\text{jj})$
 - GMSB Model with $ZZ + \text{MET}$
 - $4l$
 - $Z(\text{ll})V(\text{jj})$



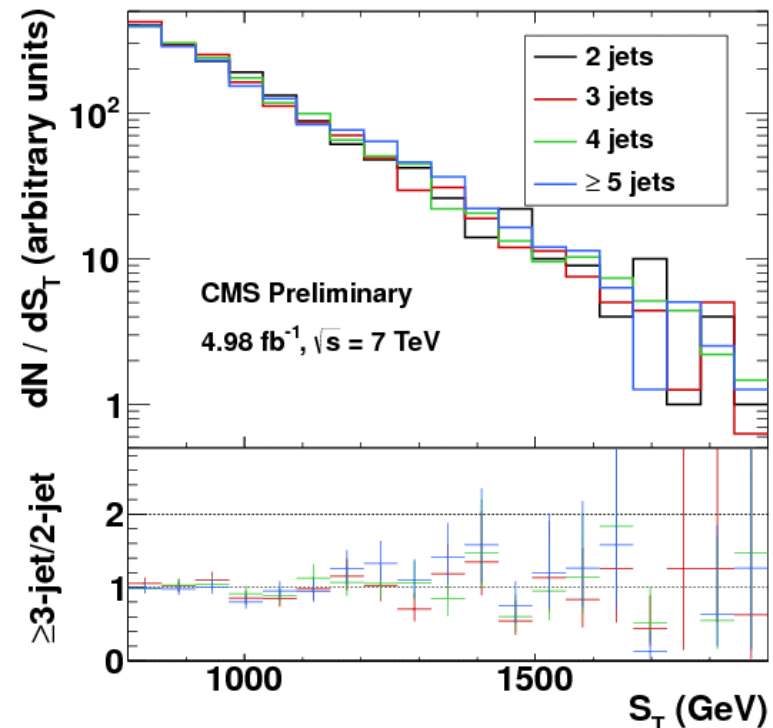
Details coming soon at SUSY12

What's new?: Stealth SUSY with Photons



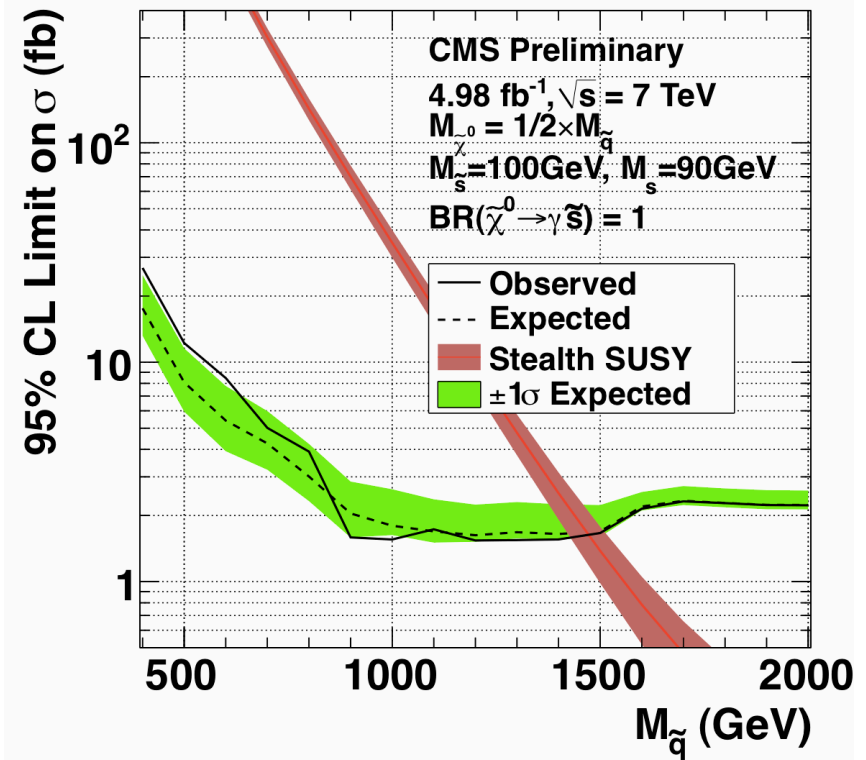
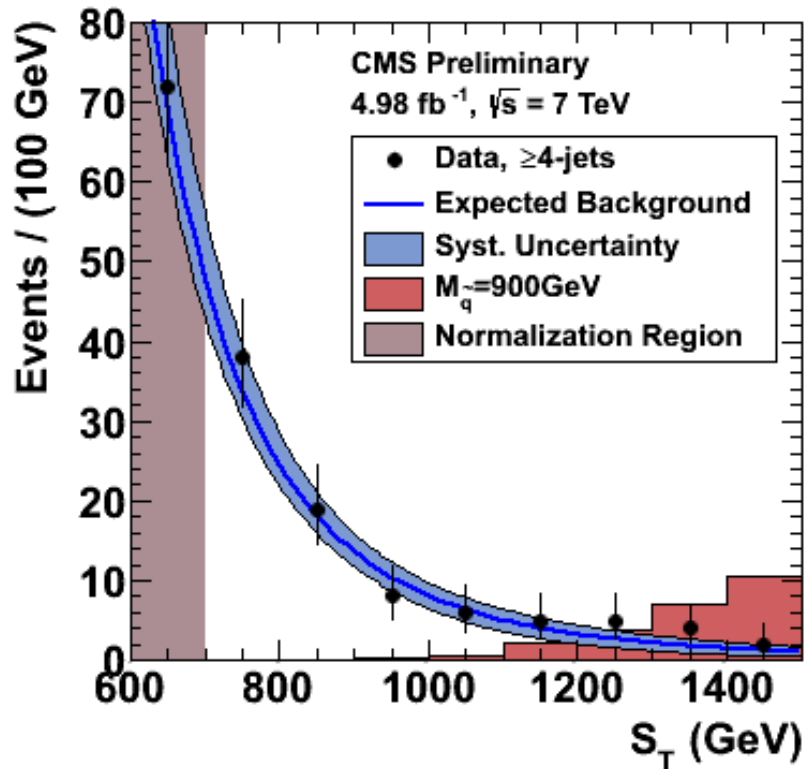
$$S_T = \text{MET} + \sum_{\gamma} E_T + \sum_{\text{jets}} p_T$$

- **Signature:** Low MET from LSP produced with photons and jets
 - First search of its kind!
- Use S_T distribution
- Background estimated using S_T scaling *a la Black Hole* analysis
 - Shown to work in photon+jets events
 - No dependence on jet multiplicity
 - Use 2, 3 jet bins to predict bkg in ≥ 4 jet events



Stealth SUSY with Photons

Functional form: $1/x^p$ where $x=ST/\sqrt{s}$
 Normalization region 600-700 GeV



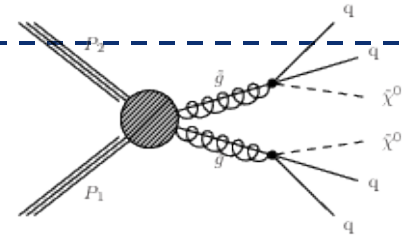
Observed: $M_{sq} > 1430$ GeV
 Expected: $M_{sq} > 1420$ GeV

What have we learned?

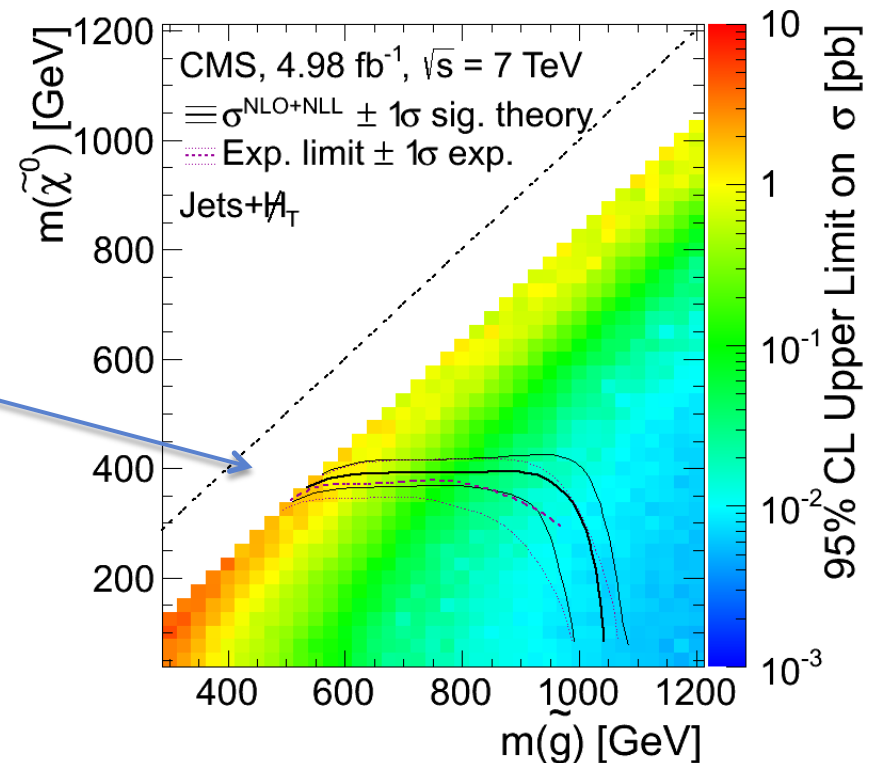
- SMS results can give an idea about the difficult regions we want to go after:

- Very low mass splitting region
 - Low efficiency
 - Low MET \rightarrow need ISR to get significant MET
 - \rightarrow Uncertainties in modeling of the ISR (recall, signal samples generated with Pythia); region along diagonal removed
- Stop pair production
 - Low mass and $\sigma \cdot \text{BR}$
 - combined challenges

Example:



$$pp \rightarrow \tilde{g}\tilde{g}, \tilde{g} \rightarrow qq\tilde{\chi}^0; m(\tilde{q}) \gg m(\tilde{g})$$

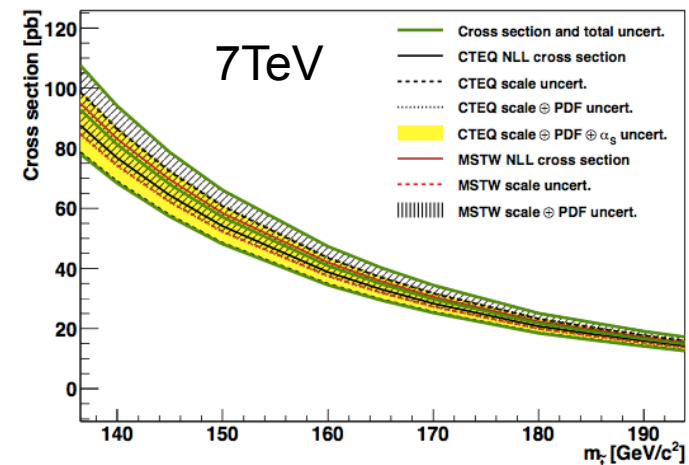
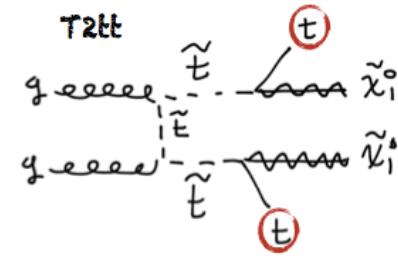


Challenges

- I would like to focus on the following challenges we are facing and discuss them; feel free to interrupt; can continue the discussion in the parallel group session
 - Challenges of searches for stop pair production
 - Compressed spectra / ISR
 - MC issues (related to above)

Direct Stop Searches

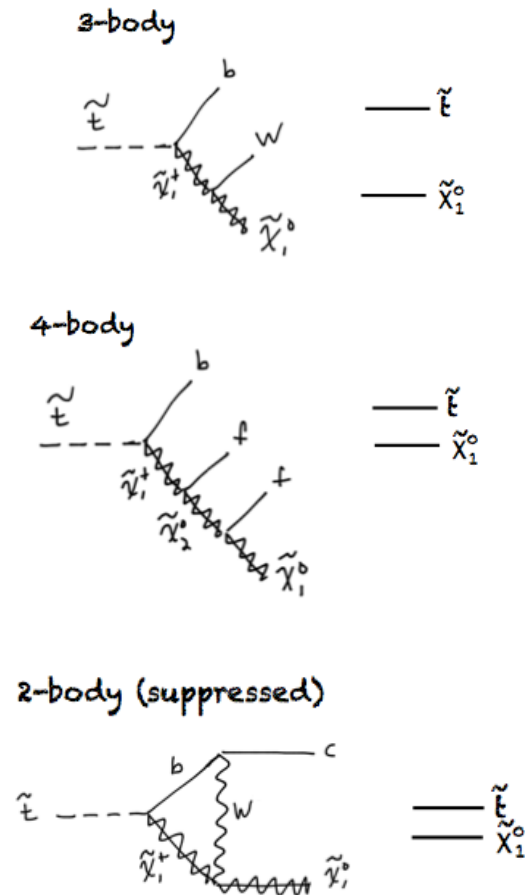
- **Searches are challenged by:**
 - Small cross sections
 - Large background from $t\bar{t}$ production
 - Similar kinematics as $t\bar{t}$ production
- **Ongoing targeted efforts in:**
 - Each channel (0,1,2 leptons)
 - Exploiting kinematic variables
 - M_T , N_{jet} , angles, $MT2$, etc
 - Exploring use of more sophisticated tools such as ANN
 - **More?**



<http://arxiv.org/abs/1206.2892>

New and unexplored areas

- **More targeted stop searches, e.g.**
 - 3 body decays
 - 4 body decays
 - stop \rightarrow charm + LSP
 -
- **Stop lighter than top**
 - Different set of challenges:
 - Lower p_T , cocktail of backgrounds
 - Exploring kinematic variables: M_{lb} , p_T lepton, p_T b-jet, H_T , MET, M_T etc.
- **Very heavy stop**
 - Use boosted top tagging tools



Top Kinematics

- Although there is a lot we know about top production, there is a lot we don't know with great confidence → systematic uncertainties
- How can we control the systematic uncertainties? Need to better understand:
 - High p_T , MET, H_T tails
 - ISR/FSR
 - NLO
 - How well do we understand other processes such as
 - $t\bar{t}$ γ , $t\bar{t}$ + W, $t\bar{t}$ + Z ...
 - In addition, can benefit from top property measurements – way to validate our understanding
 - $d\sigma/dp_T$, $d\sigma/dM_{t\bar{t}}$, W helicity, spin correlations
 - Important to have a good handle on these, even as SM measurements, in order to have confidence in bkg predictions for searches
 - Will precision SM measurements provide us with a discovery?
- Anything else?

Compressed Spectra / ISR

- **What can we do now?**
 - Study ISR in data using p_T of Z's and p_T of $t\bar{t}$
 - Use to validate Monte Carlo
 - Additional theoretical guidance?
- **What can we do with the full dataset?**
 - Analyze the “parked” data:
 - Have deployed “parked” triggers for this, to be analyzed after the data-taking is over next year.
 - 4-jet and 5-jet triggers with (staggered) thresholds and no MET
 - QuadJet50, QuadJet50_Jet20
 - HT200 trigger requiring an α_T cut
 - Razor trigger with low thresholds
 - going after lower mass and lower met
 - **Other ideas?**

Monte Carlo Challenges

- **Signal Monte Carlo**

- Currently use Pythia for signal generation
- Exploring the use of Madgraph
 - Validation needed
 - Q: Common sample generation for LHC experiments?
- Scans with fine granularity in parameter space of interest a computing challenge
 - Use Fast simulation; Full simulation adds computing challenge

- **ttbar Monte Carlo**

- Madgraph used here
 - Comparisons with other generators (MC@NLO, Powheg) useful
- Large sample with full spin correlations being produced
 - Again a computing challenge

What are we missing?

- Full coverage for searches for stops
 - e.g. stops near top
- Broader program for RPV and Stealth (low MET)
- Full coverage for searches for EWK production
 - e.g. direct slepton production
- Full coverage of searches for long-lived (s)particles
 - Existing program in “exotica”
- Searches for higgsinos
- What else?
 - Feedback welcome!

Discussion
