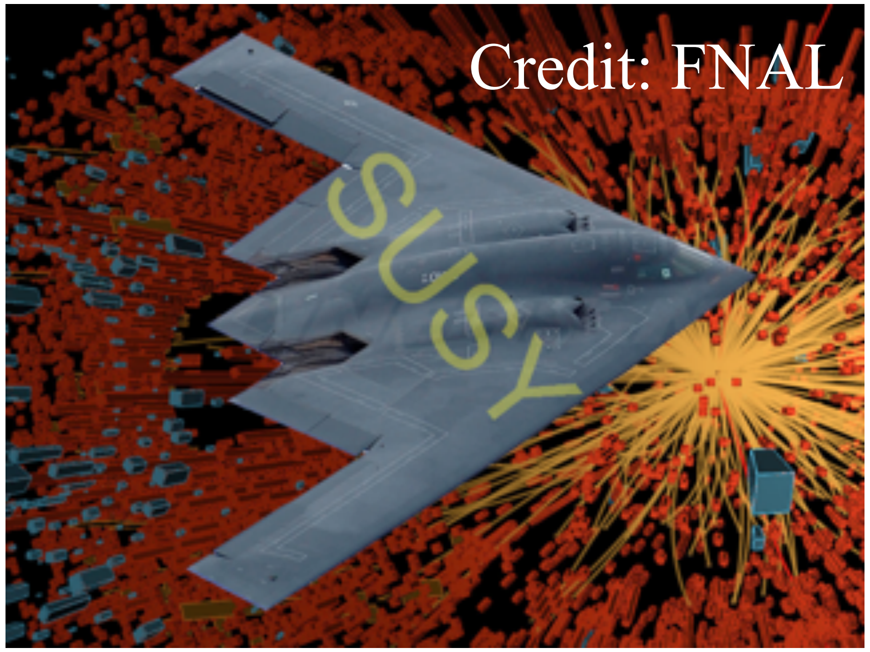
Search for stealth supersymmetry in events with leptons or photons, jets and low missing transverse energy

Lake Louise, February 17, 2015

arXiv: 1411.7255
SUS-14-009 public twiki



Ben Carlson, On behalf of the CMS Collaboration

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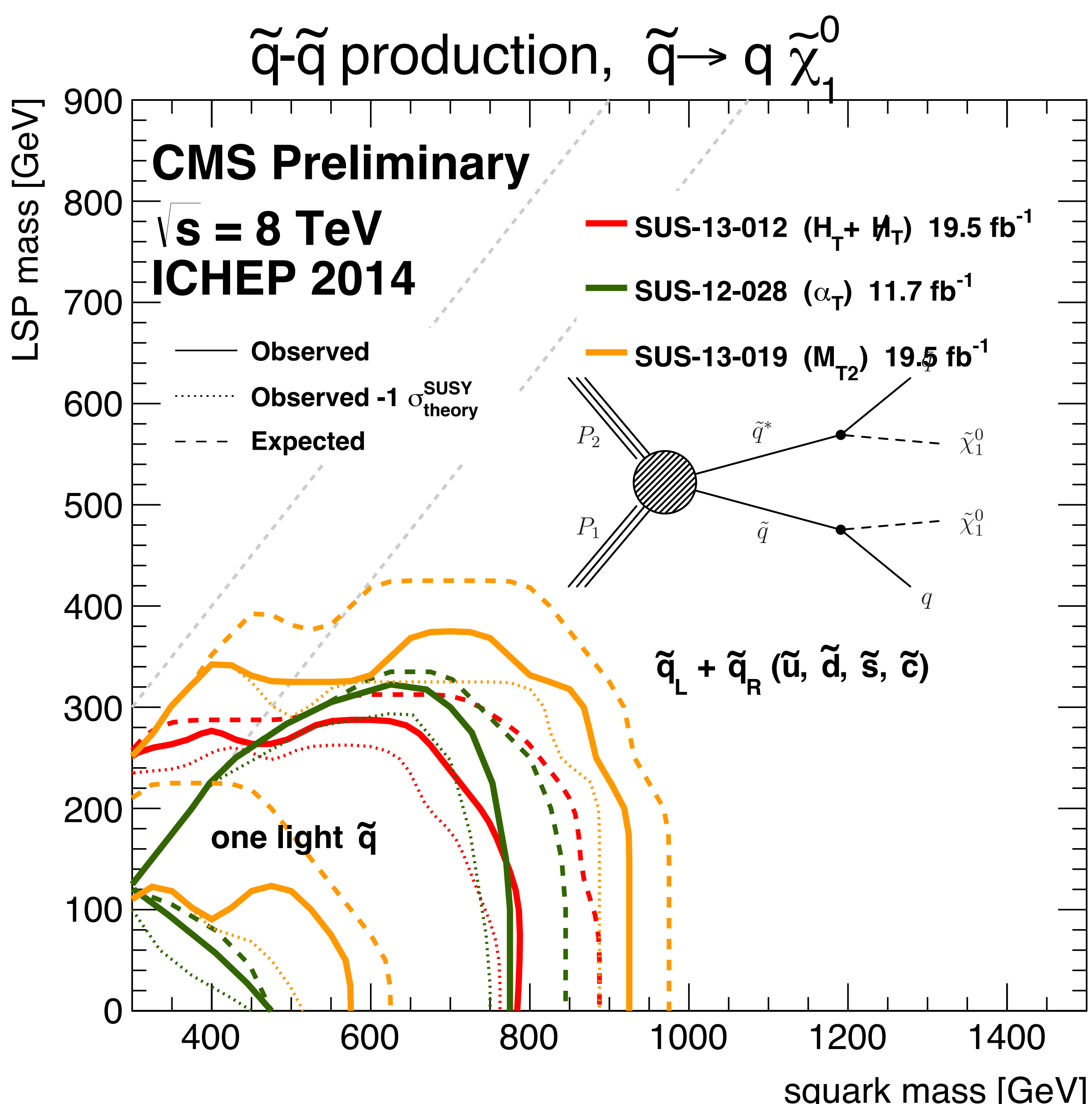
Where is supersymmetry hiding?



Examples of typical SUSY searches with MET

- Many searches rely on MET from undetected LSP ($\tilde{\chi}^0$)
- These searches exclude first and second generation squark masses up to 1 TeV
- Need complementary low MET searches motivated by:
  - Compressed spectra, R-parity violating decay, **stealth** SUSY

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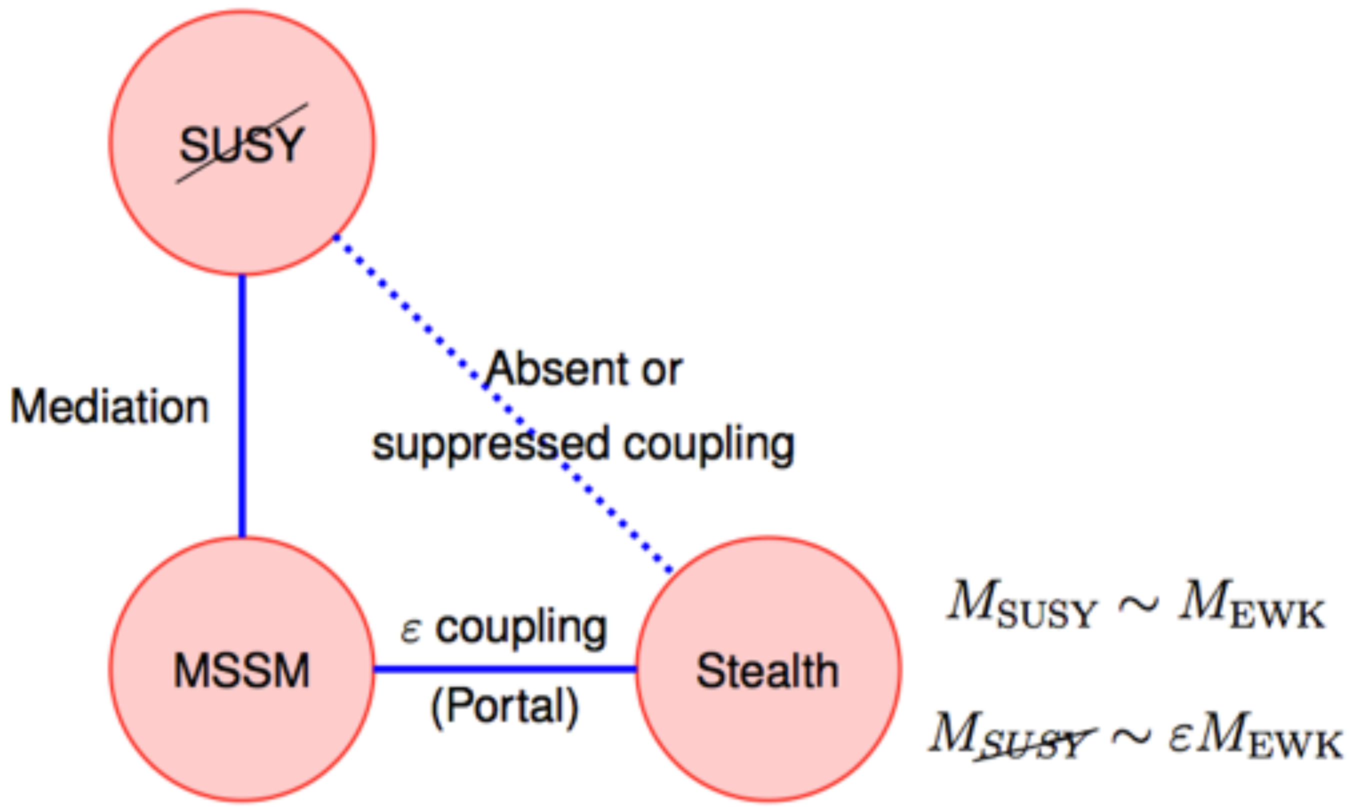
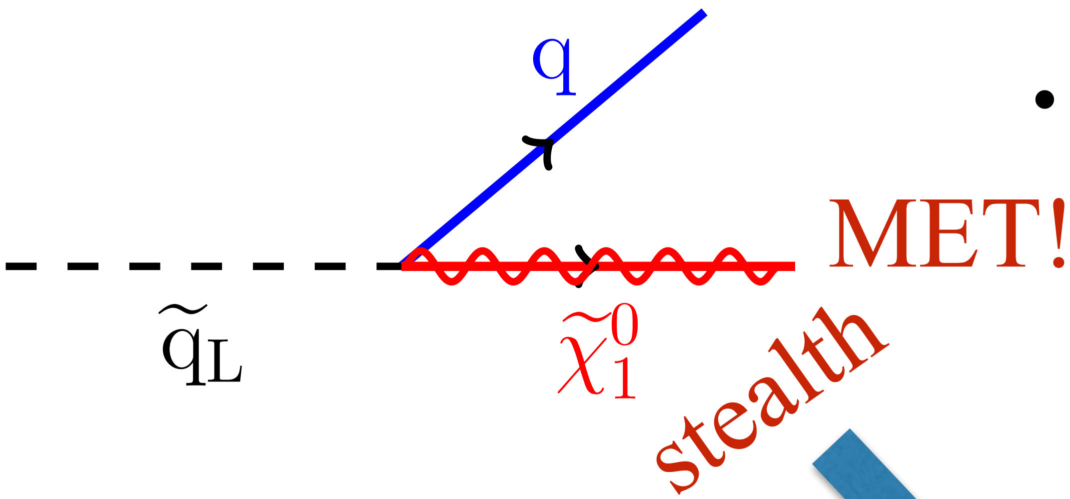
Stealth mechanism

arXiv: 1105.5135, 1201.4875
Fan, Reece, Ruderman

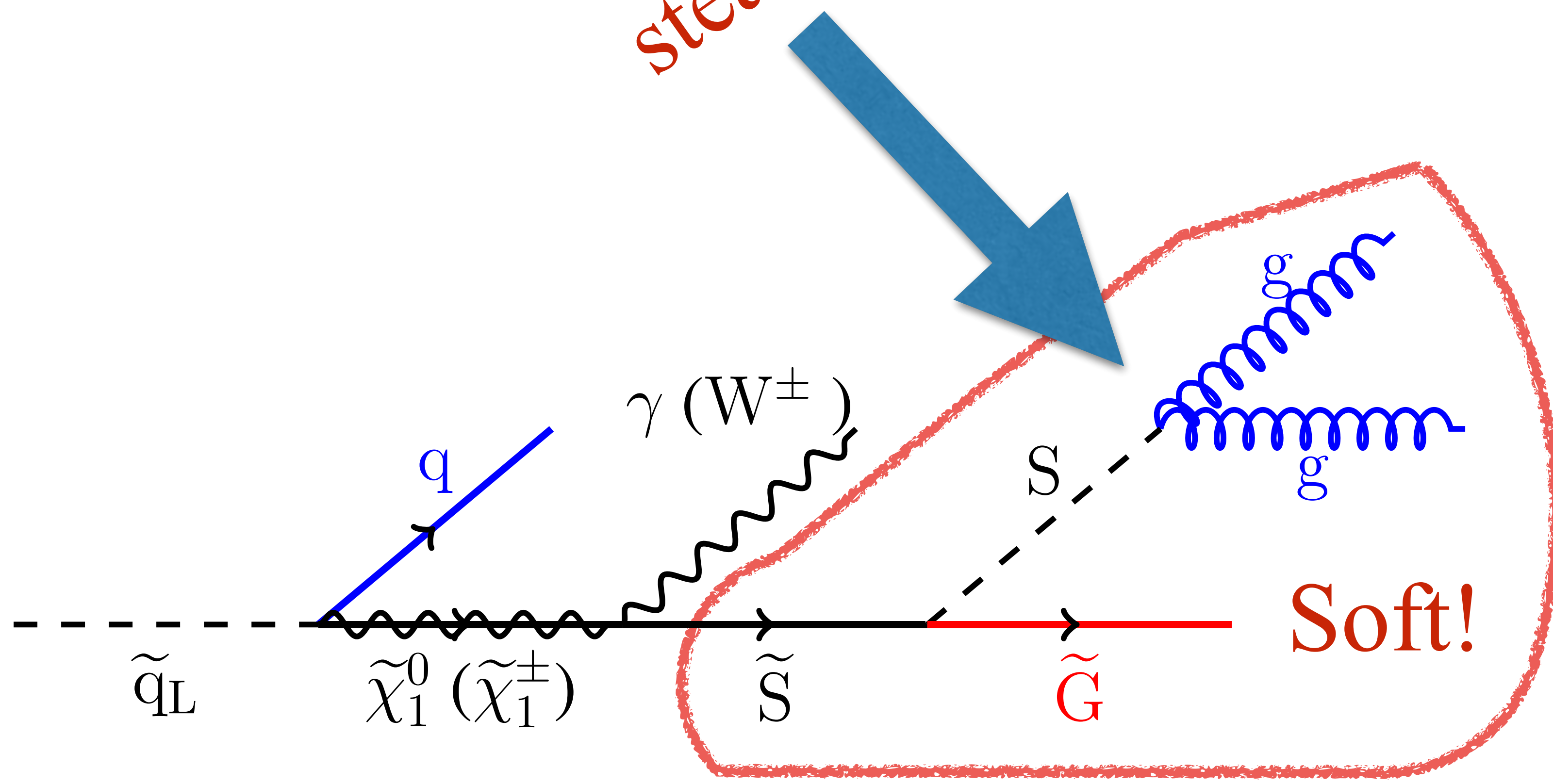


- Assume usual SUSY **breaking sector** with some mediation to **MSSM**
- Introduce hidden sector $\tilde{S}$, S
  - No coupling to SUSY breaking sector
  - SUSY approximately conserved, **enforcing mass degeneracy**
  - $\delta M = M(\tilde{S}) - M(s)$ small

Stealth SUSY



- Typical squark decay that terminates in high p_T, undetected LSP
  - Results in substantial MET



- Allow gaugino to decay to hidden sector with mass degenerate superpartners ($\tilde{S}$,S)

- **Low MET** signature generated naturally from small δM, **required** by the fact that SUSY is conserved in the **stealth sector**

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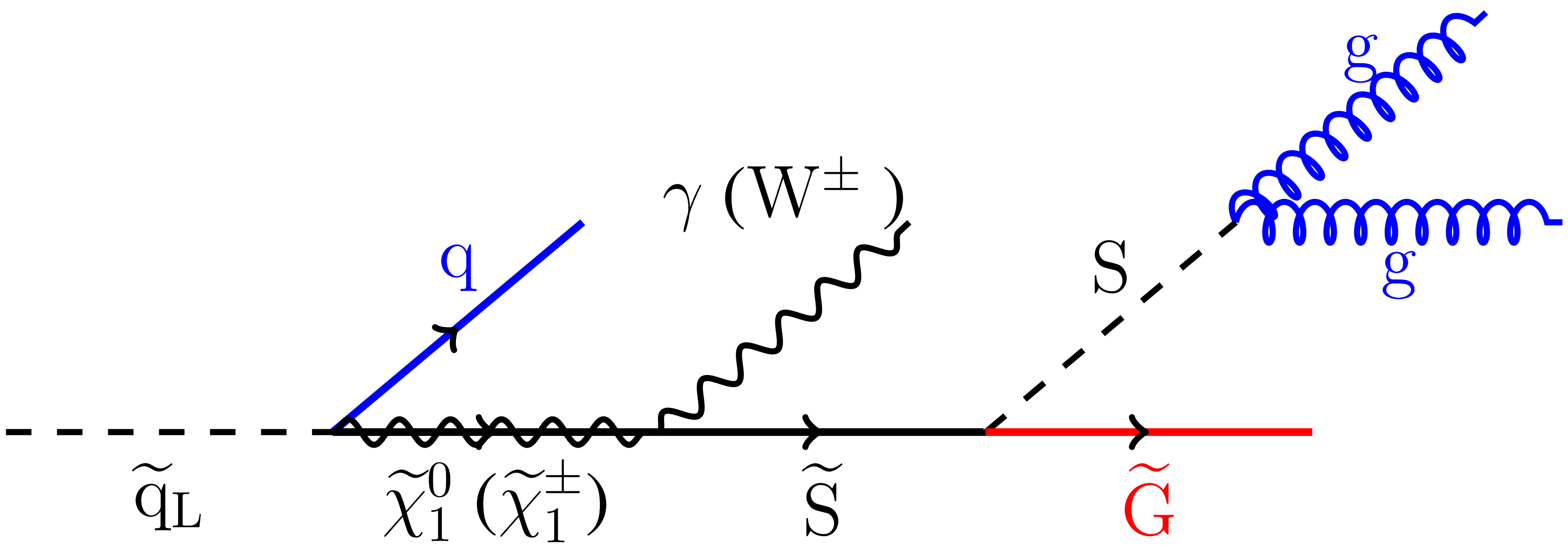
Stealth SUSY signature



- Signature: **6 jets** and **WW ($\gamma\gamma$)**
- Analysis targets **general set** of final states with photons or leptons, jets and **no MET** requirement
- Current search strategies are insensitive to this model

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Analysis overview

Search separately for WW ($\gamma\gamma$) decays
Use selections:

- **Electron & muon (eμ)**
  - Dominant background: ttbar
  - Selection designed to reduce QCD, W+jets, and DY
- Two **photons ($\gamma\gamma$)**
  - Dominant background: QCD
  - Low cross section from QCD with $\gamma\gamma$

- Use variables: N_{jets}, S_T

S_T: total transverse energy

$$S_T = \sum_{jets} p_T + \sum_{\substack{leptons\\(Photons)}} p_T + \not{E}_T$$

$S_T \sim 2 \times M_{squark}$

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Selections and trigger

eμ

- Isolated **muon** trigger
- Offline selections:
  - Muon $p_T > 30$ GeV
  - Electron $p_T > 15$ GeV
  - Jet $p_T > 30$ GeV
  - 0 b-tagged* jets

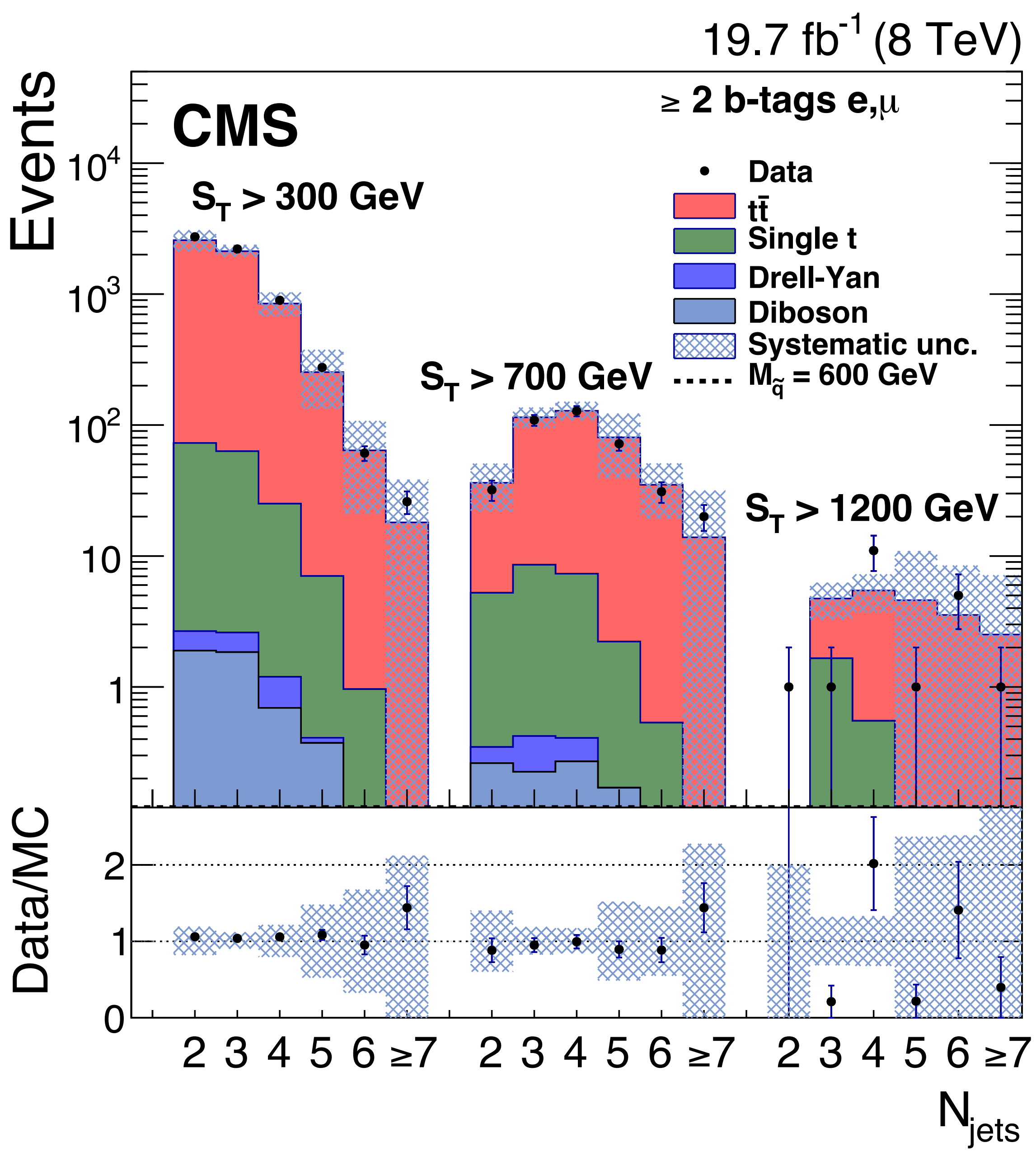
*combined secondary vertex, BTV-13-001

$\gamma\gamma$

- Isolated **diphoton** trigger
- Offline selection
  - $p_T(\gamma) > 40$ (25) GeV
  - Jet $p_T > 30$ GeV

Top background estimation for eμ

- Strategy: apply **normalization** and **N_{jets}** shape corrections to MC samples (MadGraph + Pythia) derived from **control samples**



- Dominant SM background: ttbar
  - Shape from ≥ 2 b-tag
  - Normalization (0 b-tag) from 2-3 jet

- **Jet multiplicity** well modeled by MC
- **Uncertainties** from variation of renormalization/ factorization scales

Background estimation for eμ analysis

- DY contributes to eμ through **$Z \rightarrow \tau\tau$**
- **Estimate DY** from dimuon mass < 130 GeV
- Backgrounds with a **non-prompt lepton**: small

Sample	Leptons	N_{jets}	$N_{\text{b-jets}}$
Search	$e^{\pm}, \mu^{\mp}$	≥ 4	0
Top shape	$e^{\pm}, \mu^{\mp}$	≥ 2	≥ 2
Top normalization	$e^{\pm}, \mu^{\mp}$	<4	0
Drell–Yan	$\mu^{\pm}, \mu^{\mp}$	≥ 2	0
Non-Prompt	$e^{\pm}, \mu^{\pm}$	≥ 2	0

- Validate background estimation in 1 b-tag **validation** control sample

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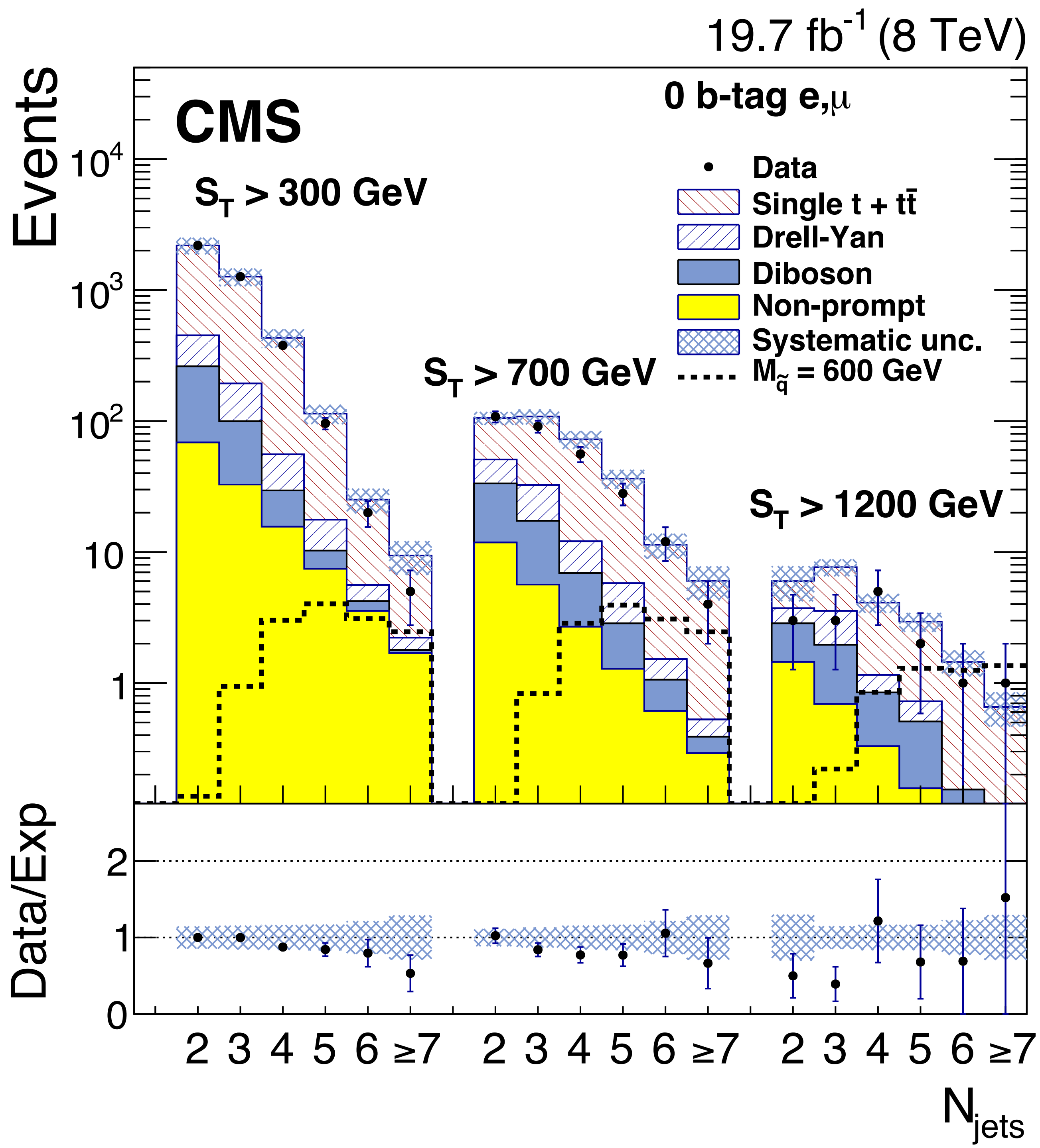
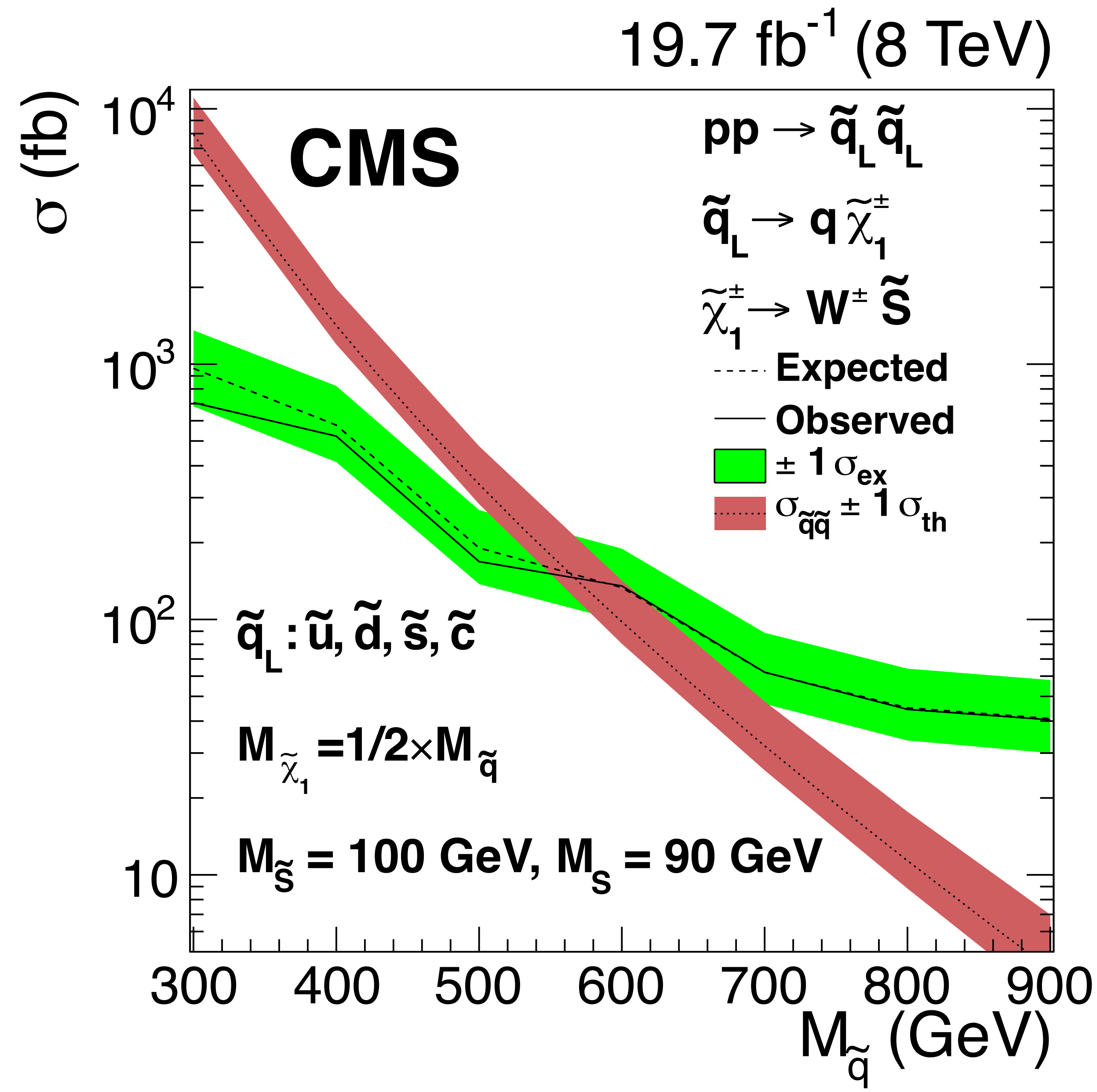
Results 0 b-tag: signal region (eμ)



- Signal tends to produce events with many jets
- Three S_T thresholds (300, 700, 1200 GeV) are optimal for all squark masses
- Dominant systematic uncertainty: statistical uncertainty on **top shape** control sample

Stealth SUSY limits: WW

- Determine limits using frequentist-inspired CLs
- Combine exclusive jet multiplicity bins (4, 5, 6, ≥7)
- Use the S_T threshold with best sensitivity



- Exclude squark masses ~550 GeV

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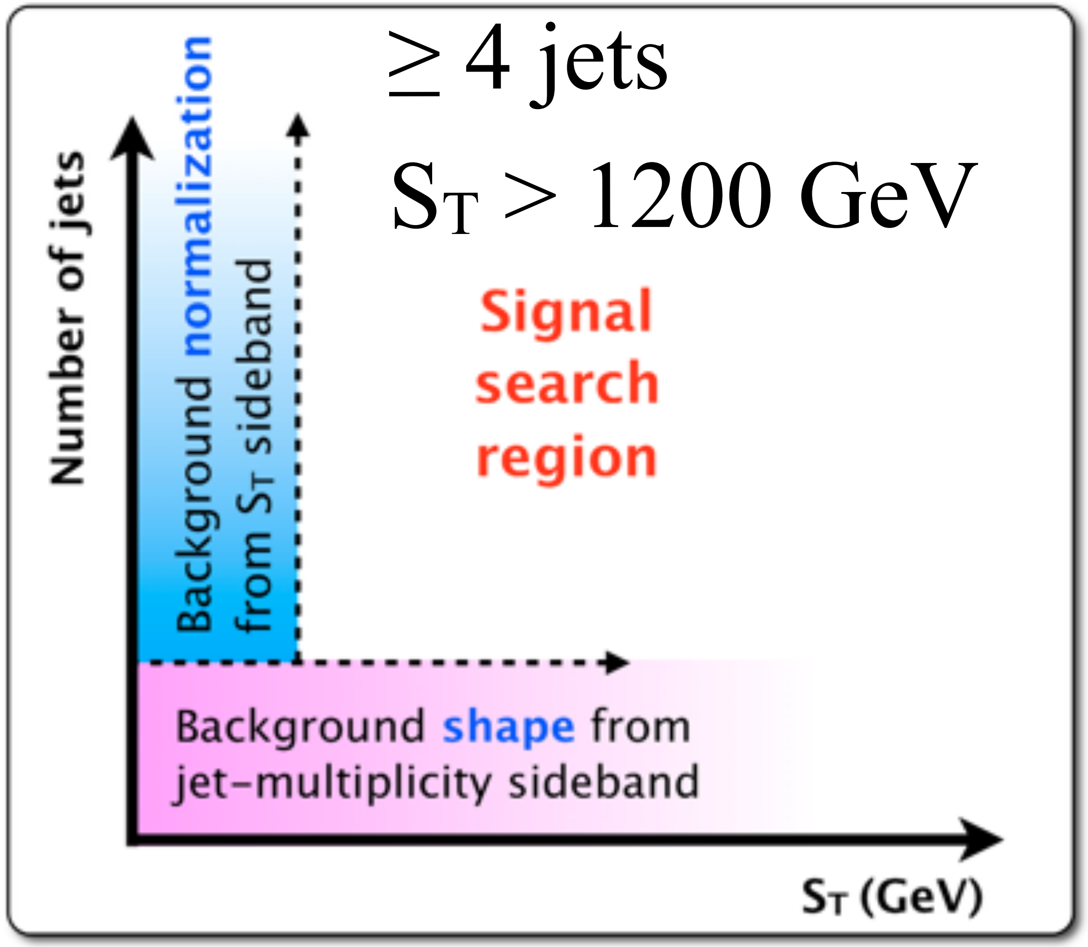
Background estimate ($\gamma\gamma$)

- S_T invariance method: S_T shape independent of N_{jets}
- Used to estimate QCD background



- Validated for:
  - inclusive QCD events (data & simulation)
  - data with 1-γ
  - simulation with $\gamma\gamma$

- Obtain **shape** from fit to 3 jet sample, and **normalize** in S_T sideband (1100-1200 GeV)

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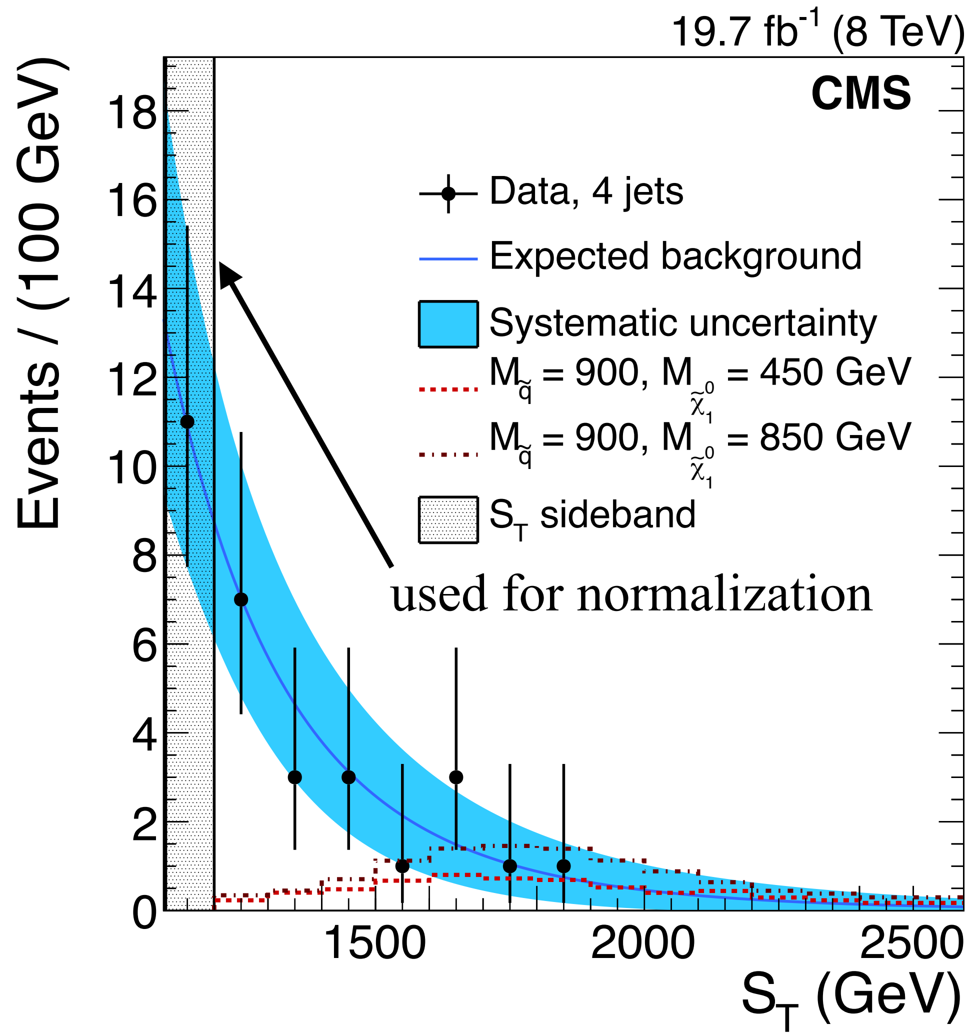
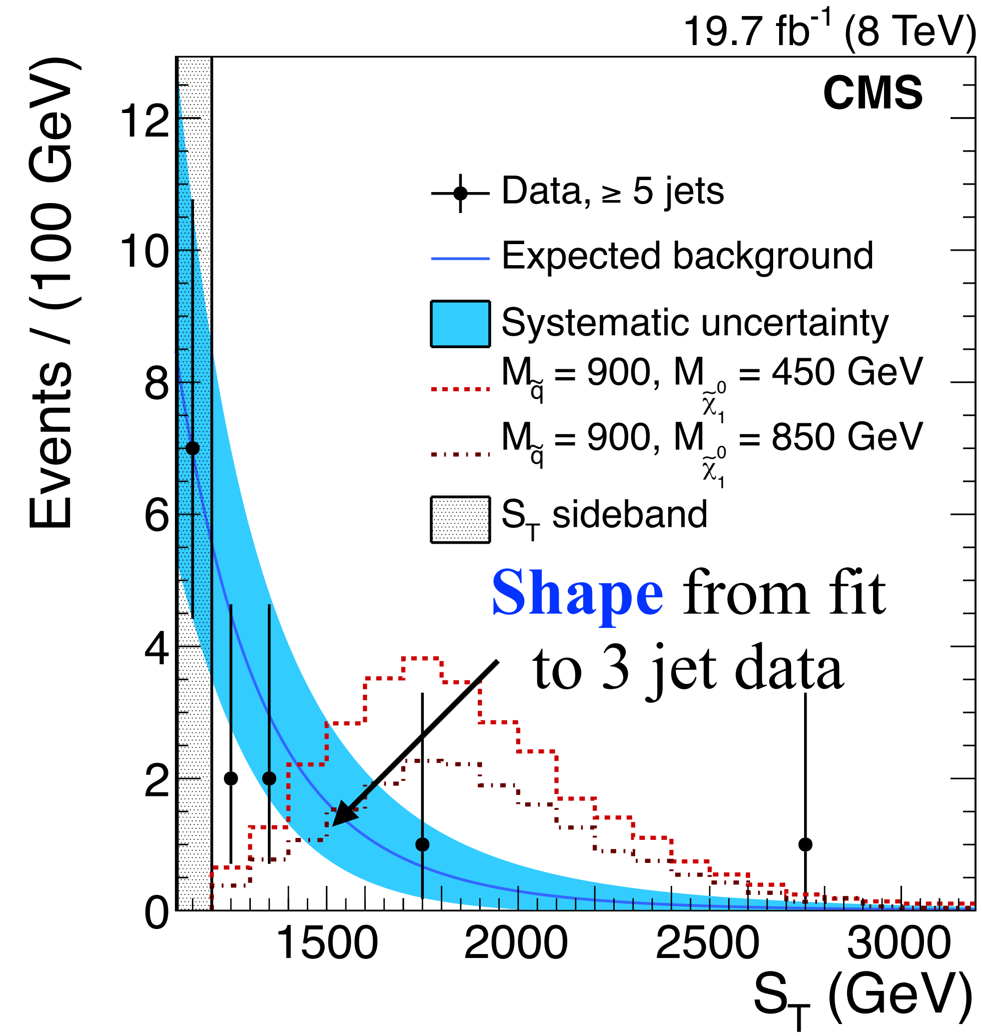
Results ($\gamma\gamma$)





- Shape in 3 jet data fit to: $1/x^{p_1 \ln S_T}$, $x = 8$ TeV
  - Functional form described 1-γ data and $\gamma\gamma$ simulation
- Systematic uncertainty dominated by **normalization** region statistical uncertainty

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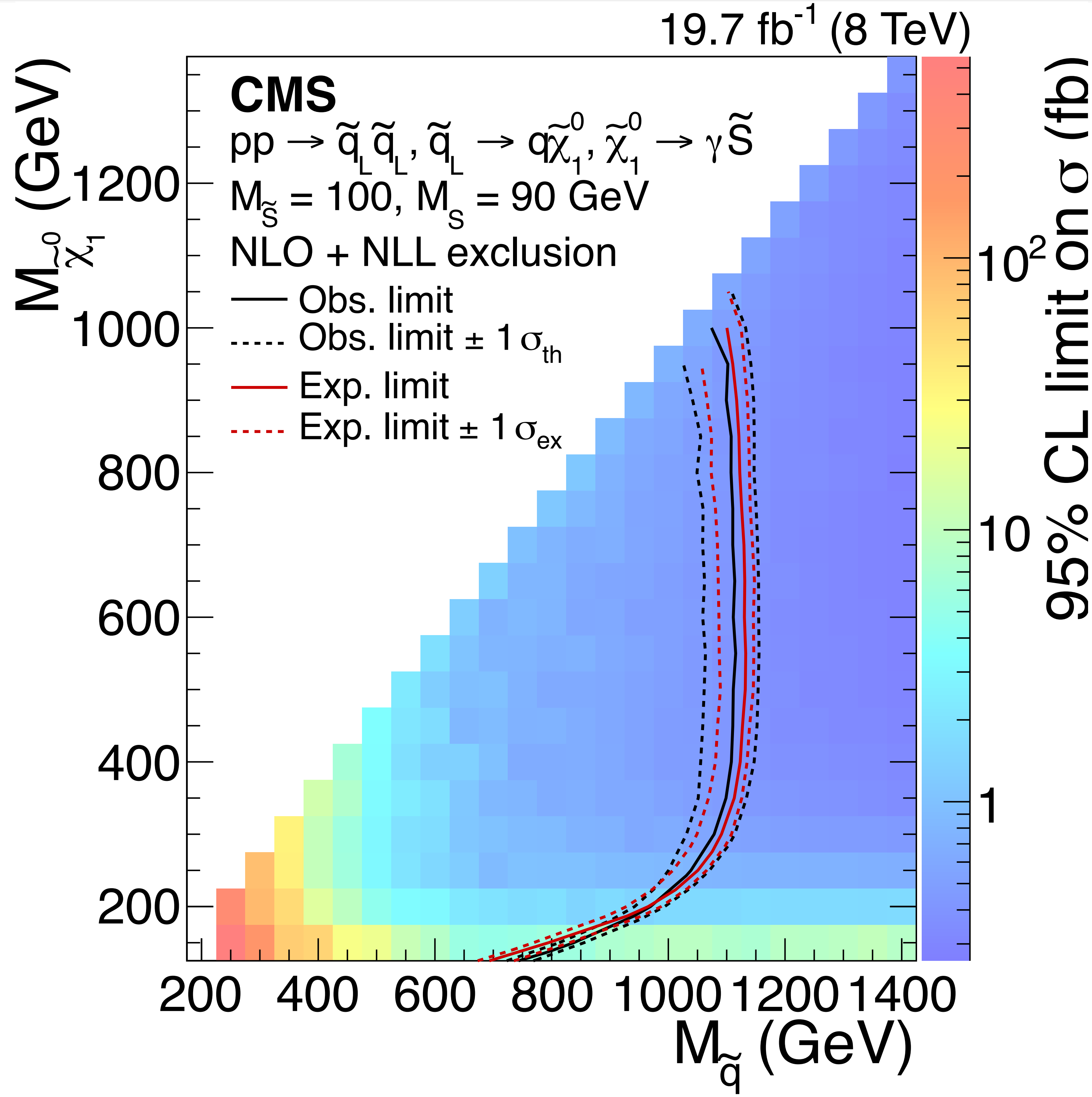
Stealth SUSY limits: $\gamma\gamma$

- Determine limits using frequentist-inspired CLs
- Combine 4, ≥5 jet bins and all S_T bins in interpretation
- Exclude squark masses ~1050 GeV



Summary

- Low-MET SUSY searches are an important complement to existing searches
  - We search in events that have either two **leptons** or two **photons** plus many jets
- Exclude squark masses below **550 GeV** for stealth decays with **leptons** and **1050 GeV** with **photons**
- Limits on squark masses for stealth models are comparable to those from models with MET
- Future direction: top squarks and Higgsino mediated top squark decays

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Backup

Drell-Yan background

- Estimate DY background (~10%) with a data-driven procedure that accounts for signal contamination
- Fit the **dimuon mass** distribution (50-130 GeV) in **$\mu^+\mu^-$ control region**
  - **DY** shape from MC
  - **Diboson** shape from MC
  - Use first order **polynomial** to describe **non-peaking components** (top, and potential signal)
  - **Floating parameters**: DY normalization (N_{DY}^{fit}), polynomial slope and normalization
- Correct DY MC in search region using $R=N_{DY}^{fit}/N_{DY}^{MC}$ for each N_{jets} bin

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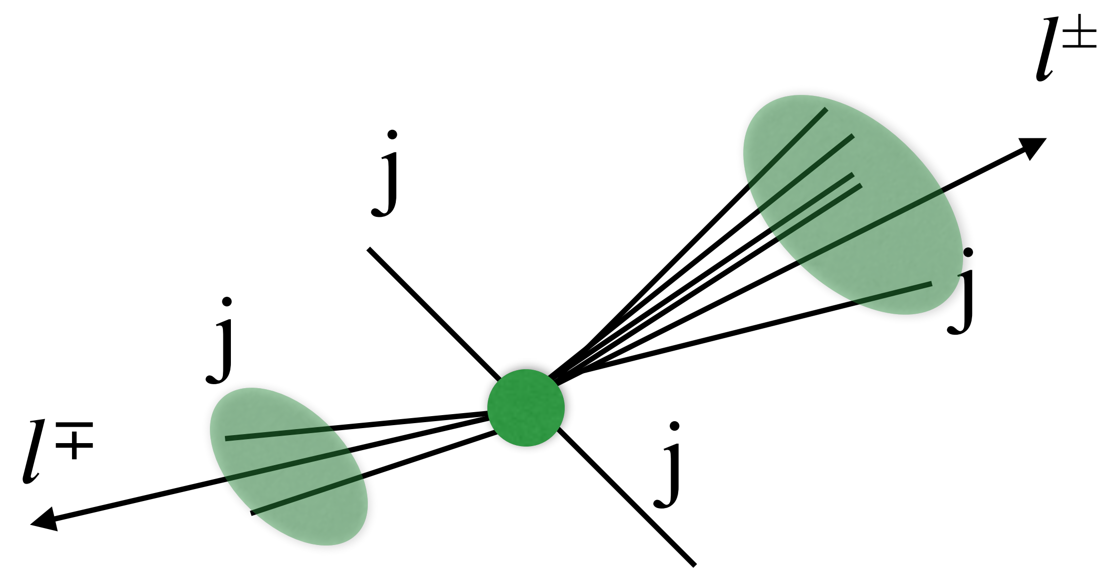
Non-prompt lepton estimate

Signal produces OS dileptons

- Use **same sign e,μ** pairs to estimate contribution from non-prompt leptons
- **Subtract** background MC from SS data to estimate non-prompt contribution to OS signal region



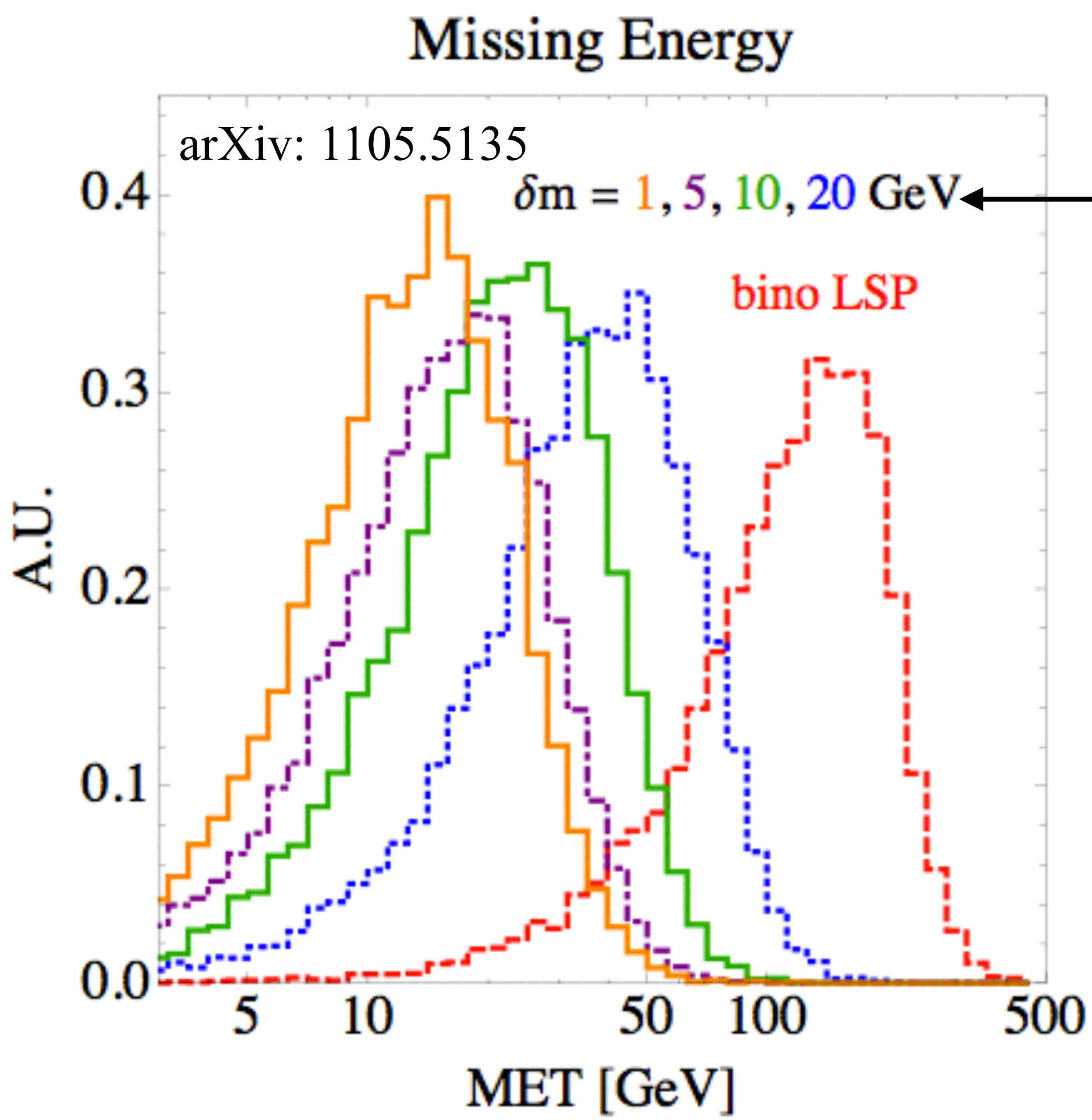
- Cartoon of sample event with non-prompt leptons

Signal efficiency

- Sample efficiency for 600 GeV squark
- The nominal branching fraction for W(W)→e(μ) is approximately 2%
- Most significant efficiency reduction comes from **isolation**

Selection	Efficiency [%]
$N_{\text{jets}} \geq 4$, $S_T \geq 300$	99.03 ± 0.05
1 loose μ, 1 loose electron, no isolation	1.70 ± 0.06
1 loose μ, 1 loose electron, loose isolation	1.10 ± 0.05
1 tight μ, 1 tight electron, tight isolation	0.96 ± 0.05
Veto additional loose leptons	0.96 ± 0.05
0 b-tagged jets	0.83 ± 0.04

No MET handle on stealth



- Mass splitting between $\tilde{S}$ and S controls MET
- As mass splitting goes down, MET goes down

Stealth SUSY has a variety of signatures:
jets, gauge bosons, but…
no MET!

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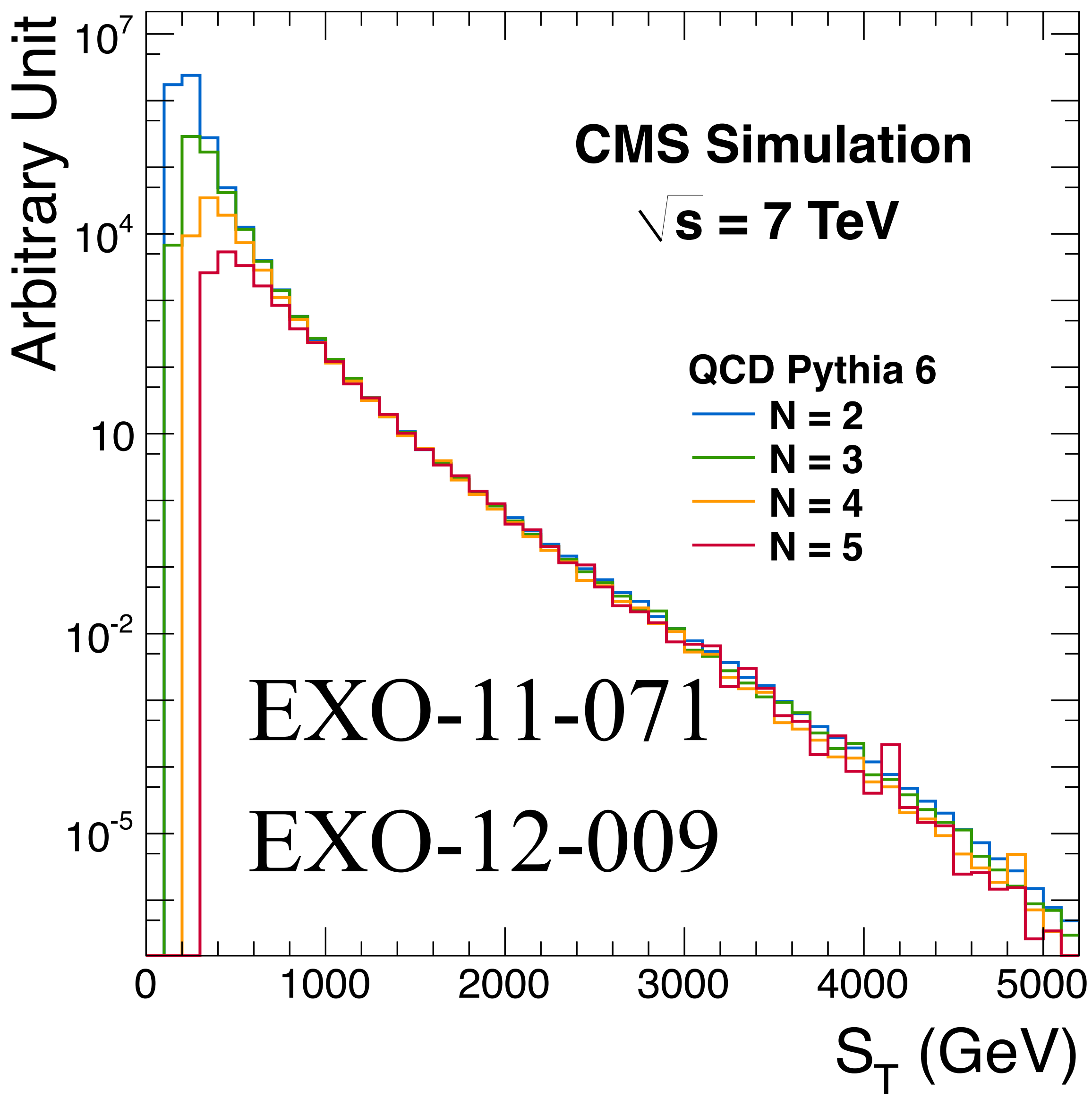
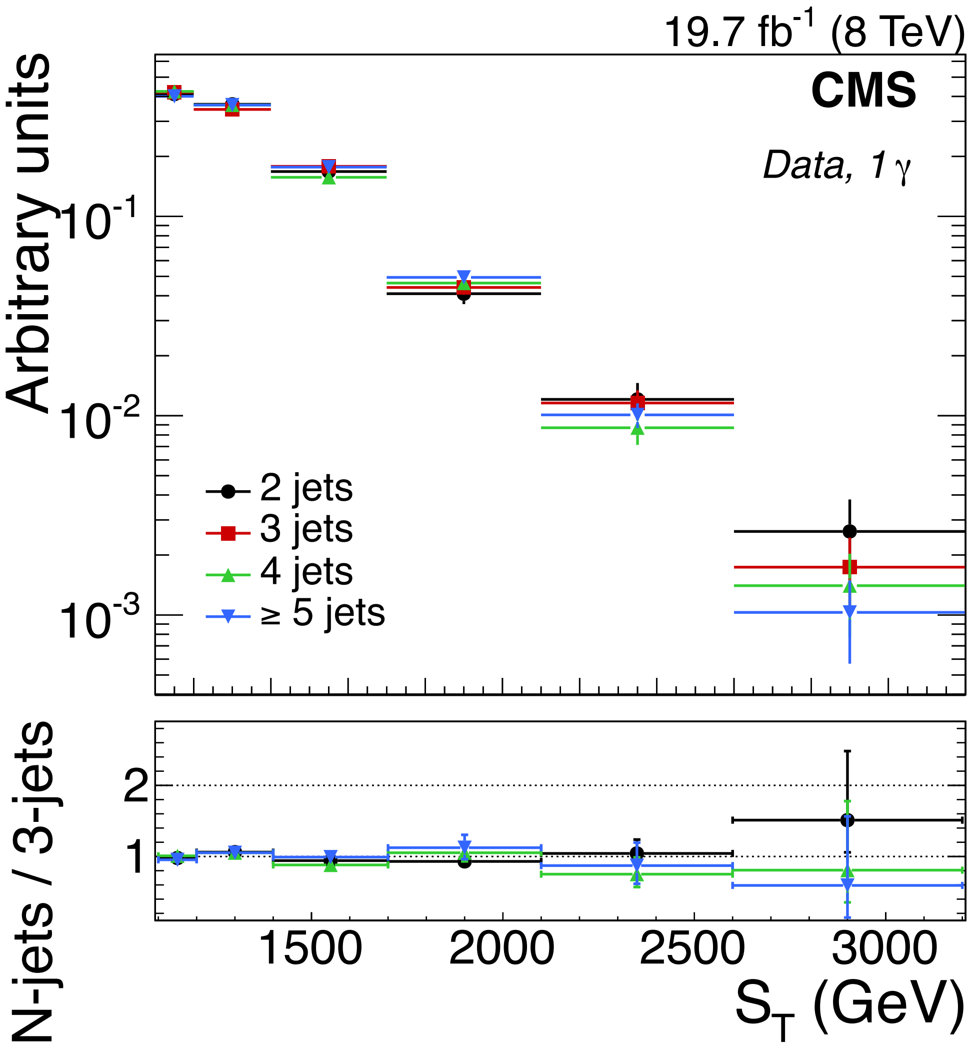
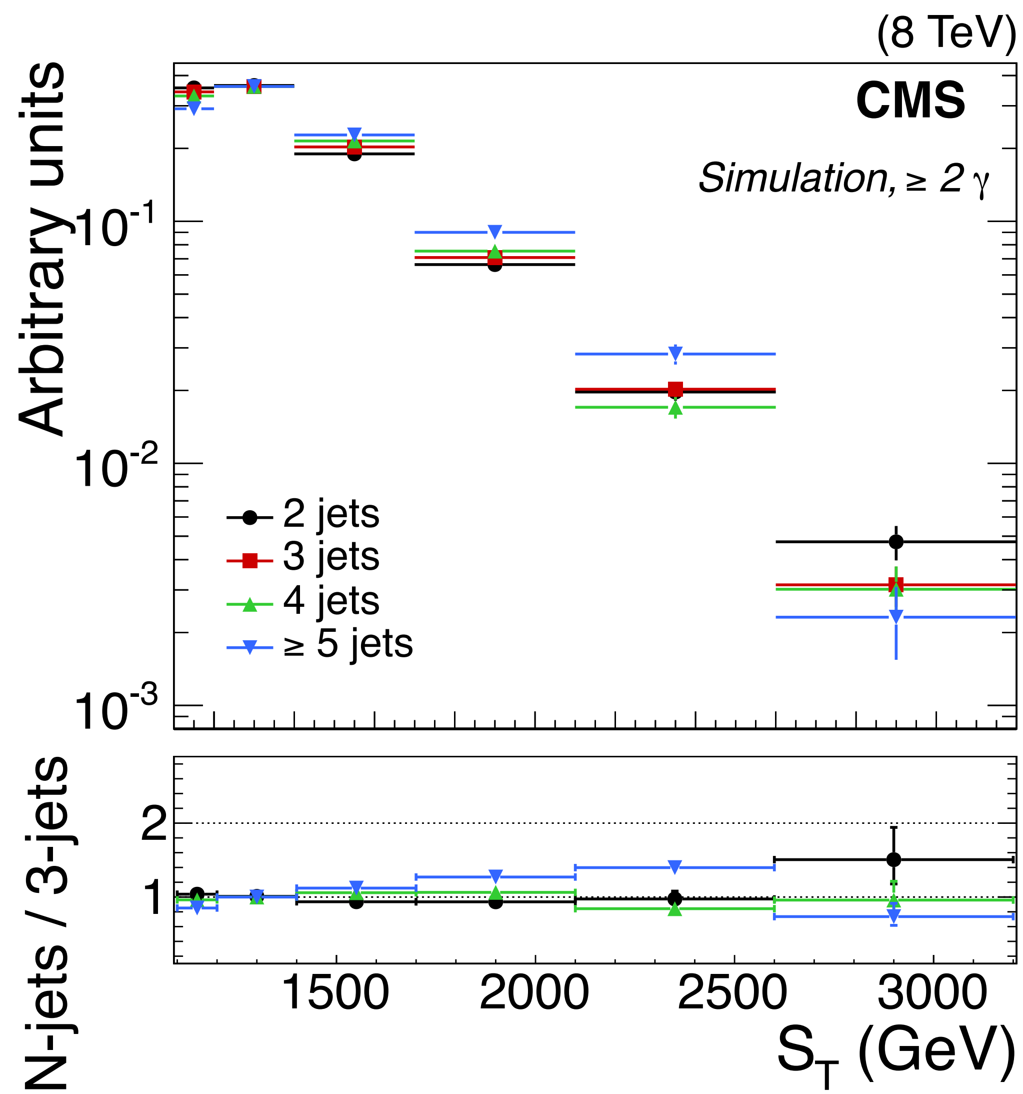
S_T invariance method: hadronic events



- Used in search for black holes to estimate QCD background in all hadronic events
- Also used to estimate QCD events with photons in SUSY search at 7 TeV (SUS-12-014)

S_T invariance with γ or $\gamma\gamma$





- S_T shapes do not depend on N_{jets}

Region	N_{jets}	S_T (GeV)
Search	≥ 4	>1200
S_T sideband	≥ 4	1100–1200
N_{jets} sideband	$=3$	>1100