



Search for new physics in events with two photons, many jets, and low missing transverse energy

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the CMS Collaboration



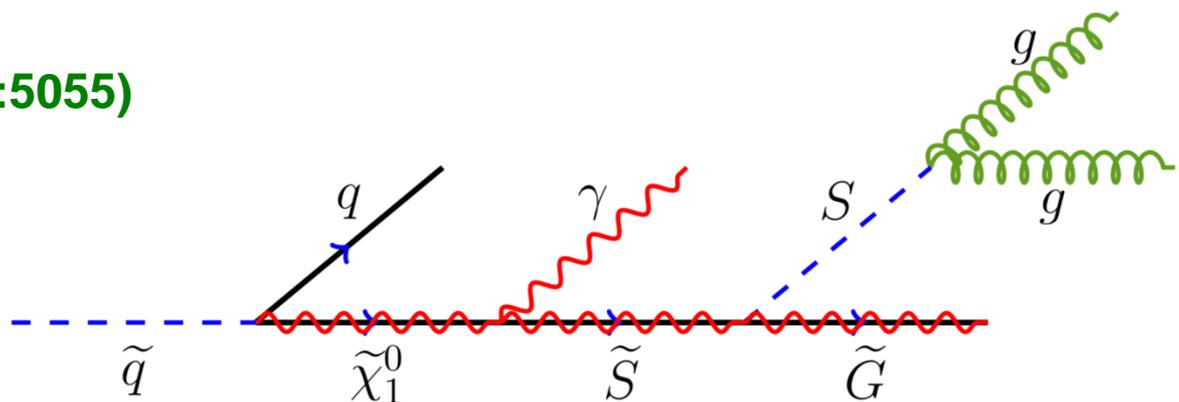
Stealth SUSY introduction



- Many SUSY searches assume large MET from heavy stable lightest SUSY particle (LSP)
- Low MET topologies relatively unexplored at LHC [1]
- **Stealth SUSY: Low MET from light, soft LSP [2]**
 - ◆ Hidden sector at weak scale, low scale SUSY breaking
 - ◆ SUSY approximately conserved in hidden sector
 - ◆ Hidden sector superpartners nearly mass degenerate
 - ◆ Soft MET spectrum from LSP, R-parity conserved

[1] Lisanti et al (arXiv:1107:5055)

[2] Fan, Reece, Ruderman (arXiv:1105:5135)





Stealth SUSY model



- **Based on T2 simplified model [1]**
 - ◆ Additional hidden sector comprising singlino and singlet
 - ◆ Gluino mass set to 1500 GeV

- **Simplifying assumptions:**

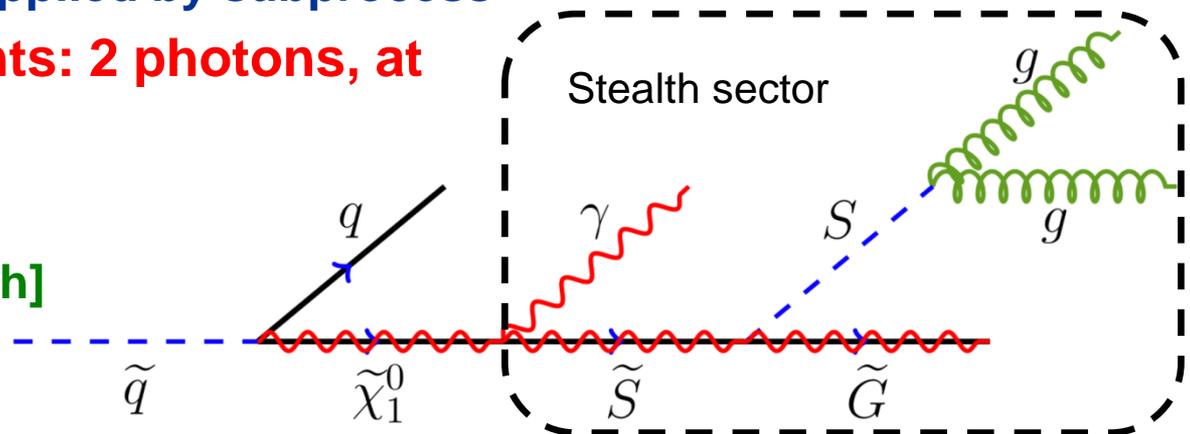
$$M_{\tilde{\chi}_1} = \frac{1}{2} M_{\tilde{q}} \quad M_{\tilde{S}} = 100 \text{ GeV}$$

$$BR(\tilde{\chi}_1 \rightarrow \gamma \tilde{S}) = 1 \quad M_S = 90 \text{ GeV}$$

- **NLO + NLL cross section and uncertainty (from scale, PDF, α_s)[2]**
- **Acceptances for dominant subprocesses from PYTHIA**
 - ◆ NLO / LO K-factor applied by subprocess

- **Selection requirements: 2 photons, at least 2 jets**

[1] CMS-PAS-SUS-11-016
[2] arXiv: 1206.2892 [hep-ph]





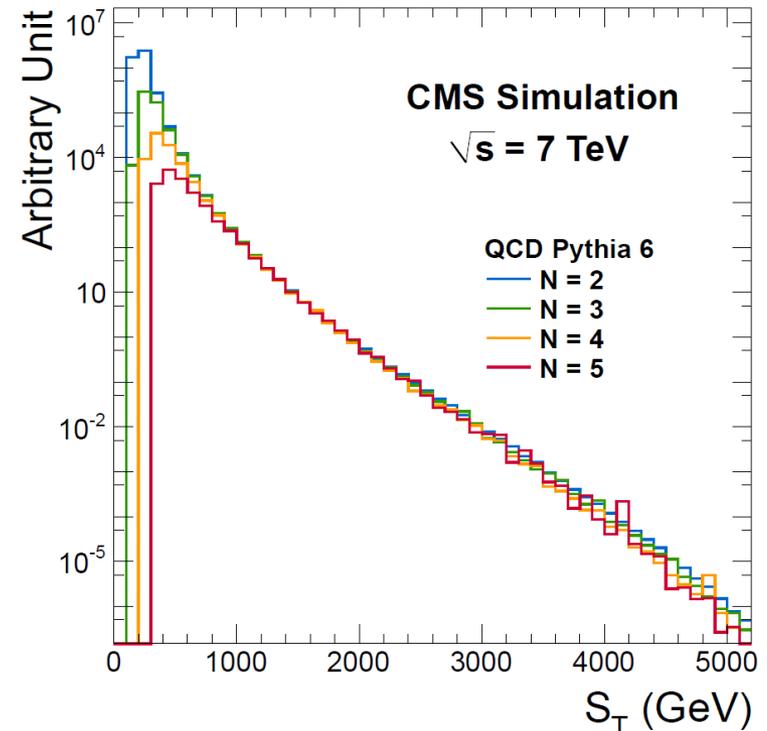
Background prediction from S_T scaling



- Predict number of background events in high jet multiplicity search region with low jet multiplicity sidebands

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

- S_T scaling of QCD in black hole search [1]:
 - ◆ S_T shape independent of object multiplicity
 - ◆ Normalization from low- S_T sideband
- Does S_T scaling hold for photons + jets?



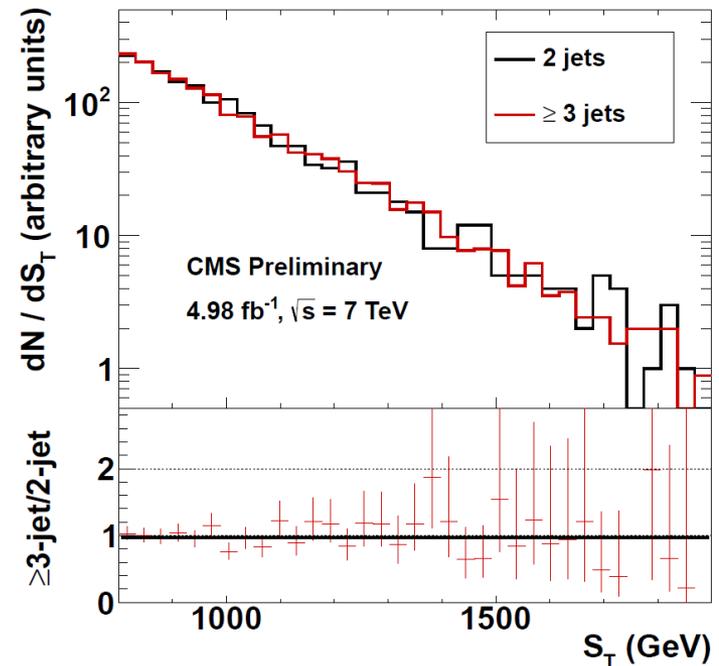
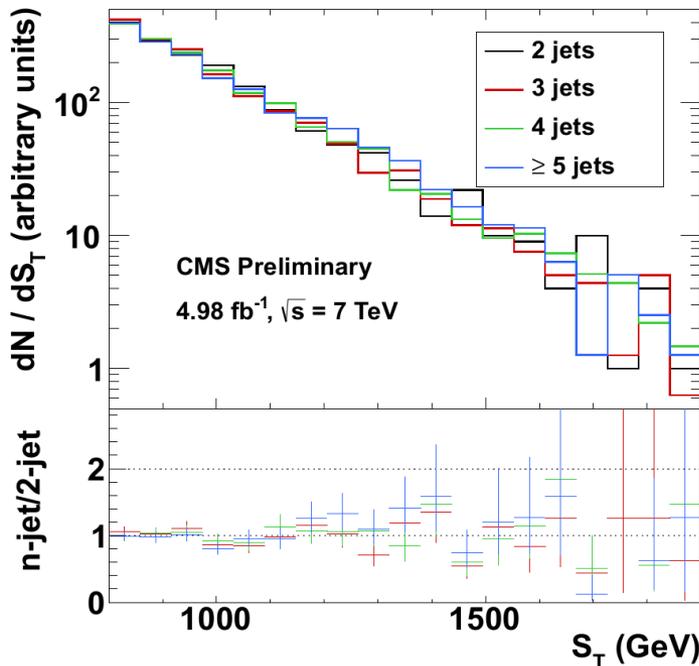
[1] CMS Collaboration [JHEP04(2012)061]



S_T scaling in photon + jets control sample



- Verify S_T scaling in large data control sample of photon + jets
- S_T shape consistent with no dependence on jet multiplicity
- ◆ Similar results from MADGRAPH diphoton sample





Overview of statistical analysis

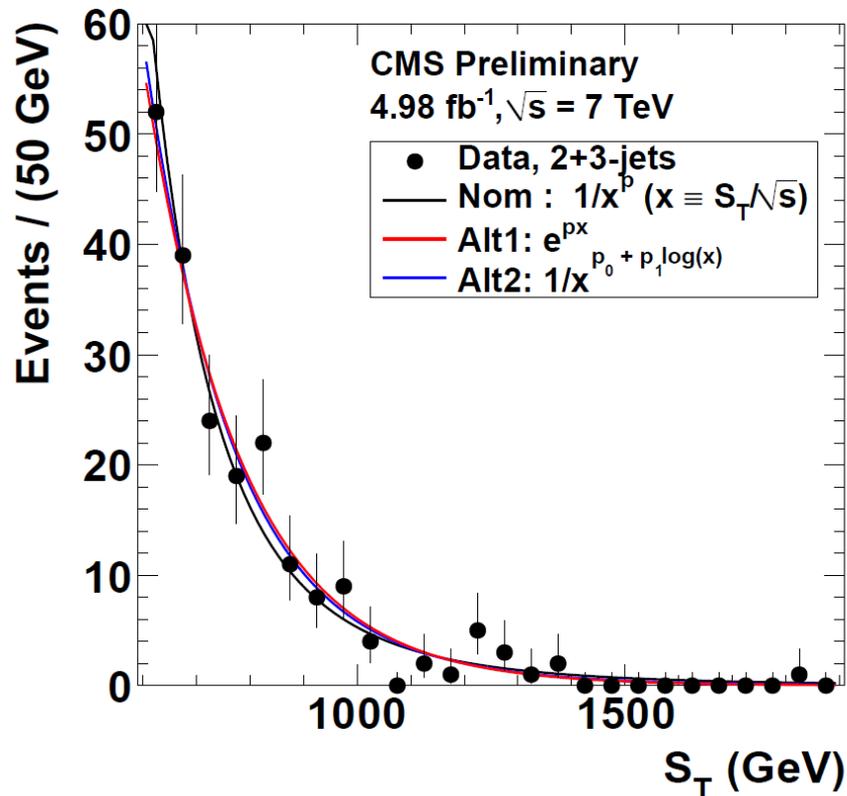


- **Background shape from jet-multiplicity sideband**
- **Background normalization from S_T sideband**
- **Using normalized shape, determine expected number of background events with S_T above threshold**
 - ◆ **Optimize threshold at each squark mass point**
- **Test for excess over background with counting experiment**
 - ◆ **In 4-jet bin and ≥ 5 -jet bin**

Region	Number of jets	S_T (GeV)
Search	≥ 4	> 700
Bkgd shape: Jet-multiplicity sideband	2 or 3	> 600
Bkgd normalization: S_T sideband	≥ 4	600 – 700

- Use background-dominated 2- and 3-jet bins

- ◆ Nominal functional form: $1/x^p$ where $x = S_T/\sqrt{s}$ fit to sample
- ◆ Two additional functions fit to estimate uncertainty due to choice of function: e^{p_0x} and $1/x^{p_0+p_1\log x}$
- ◆ Shapes consistent
 - Maximum difference taken as systematic uncertainty

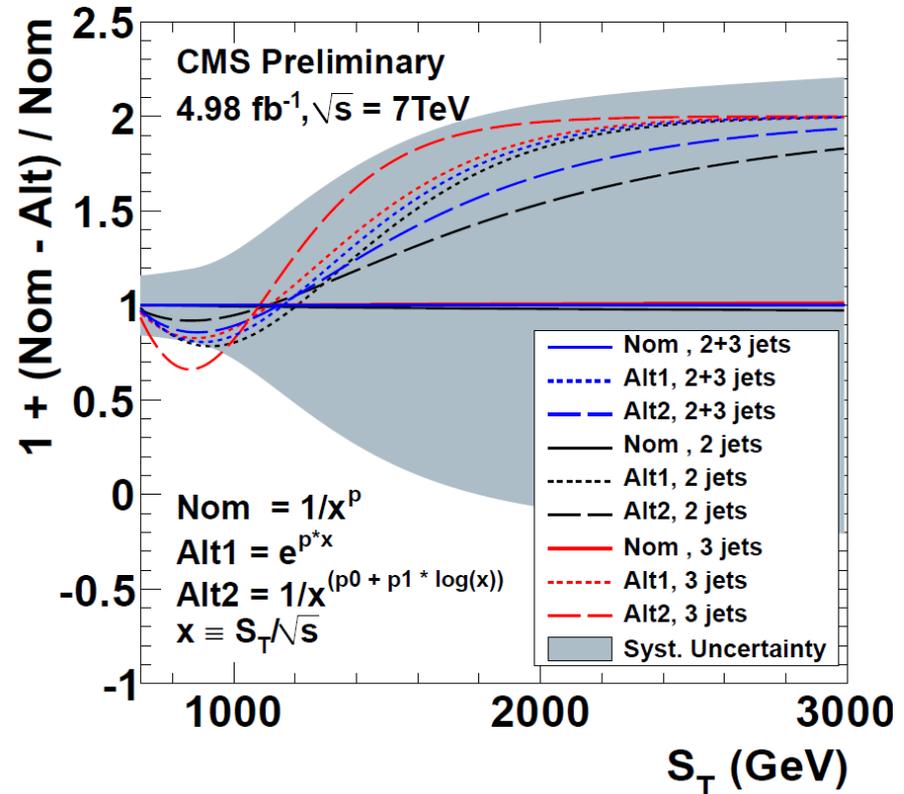




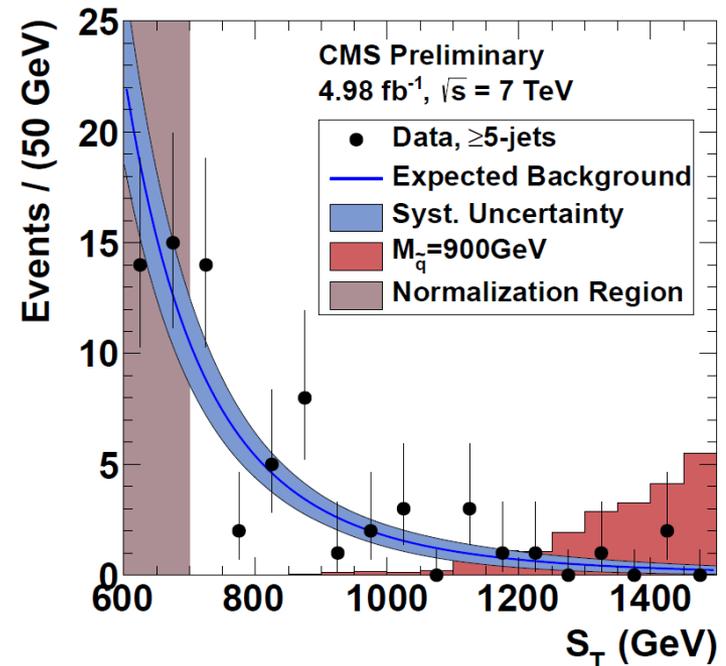
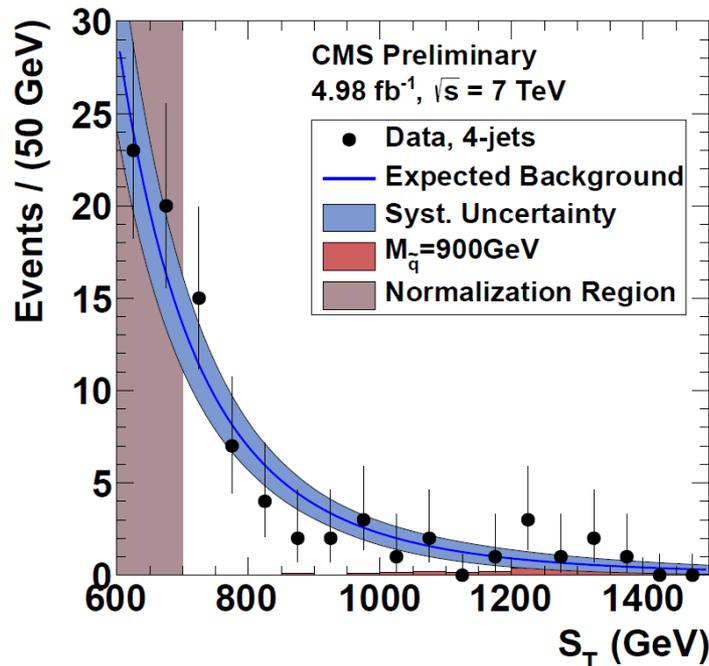
Background shape



- **Compare nominal function to two alternate functions**
 - ◆ Fit in 2, 3, and 2 + 3 jet data
- **Background uncertainty due to choice of function from largest deviation in 2 + 3 jet fits**
- **Total error band covers deviations for all functions**



- **Normalize in S_T sideband ($600 < S_T < 700$ GeV)**
- **Total event counts in all events from data (≥ 4 jets)**
- **4-jet fraction from ratio of event counts**
 - ◆ **Results consistent between data and MC**

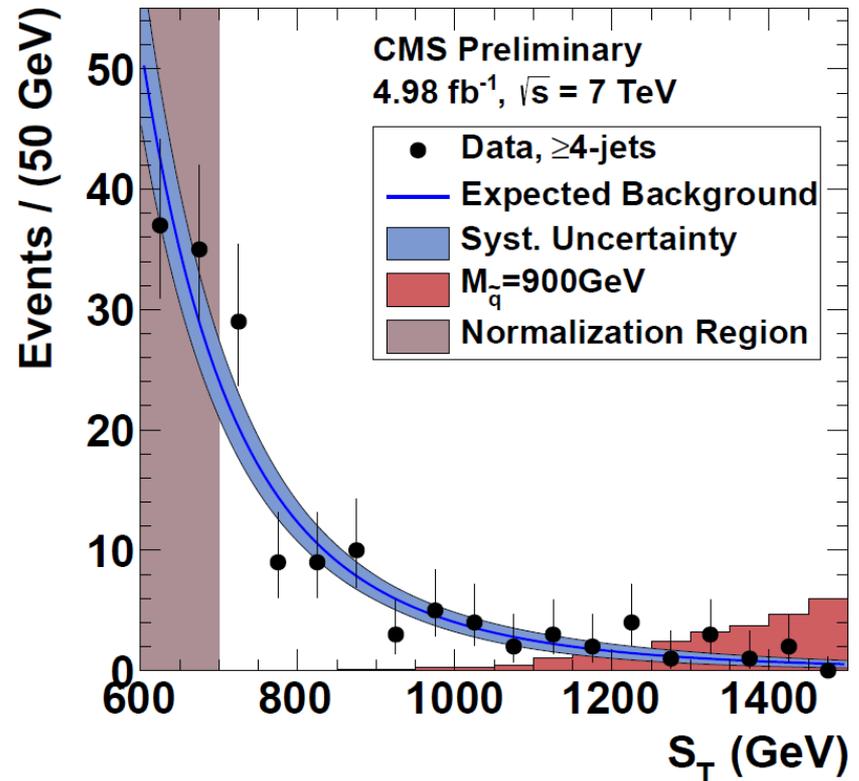




Data vs background: ≥ 4 -jets

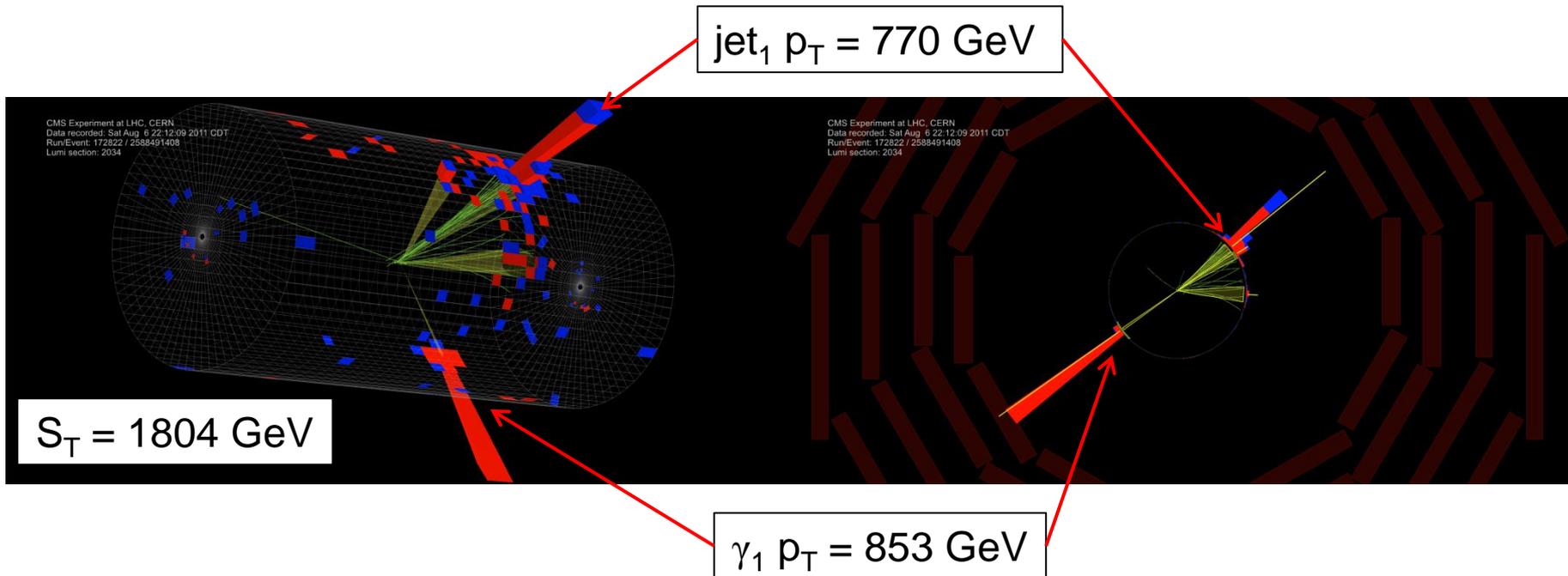


- **Good agreement between data and background expectation**
- **Determine cross section limit with counting experiment**
 - ◆ **Threshold optimized for each mass point**



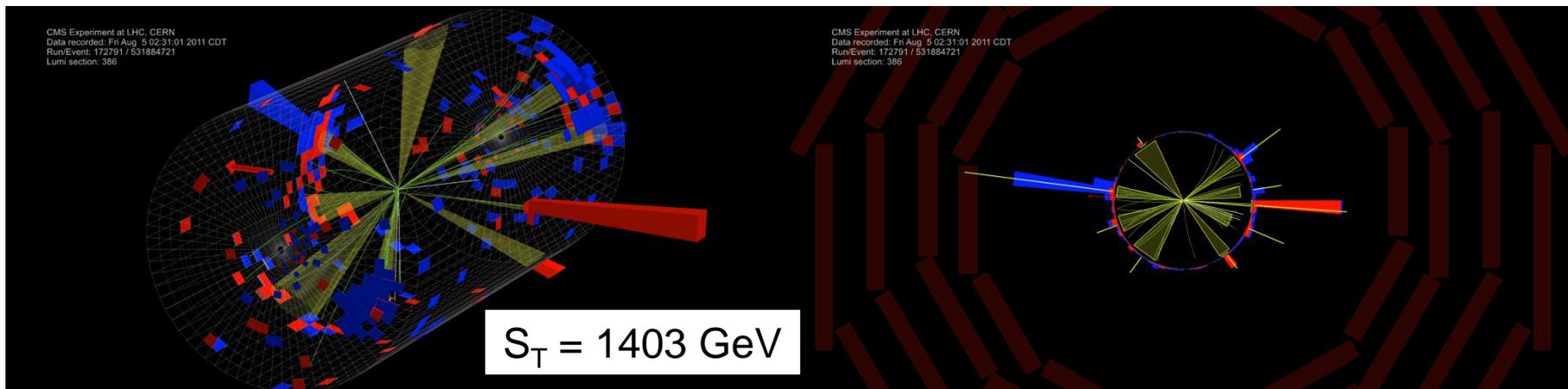
- **Highest- S_T event dominated by high- p_T photon and high- p_T jet**
 - ◆ **Fails signal selection; only 2 jets**

# jets	S_T (GeV)	$\gamma_1 p_T$ (GeV)	$\gamma_2 p_T$ (GeV)	jet ₁ p_T (GeV)	MET (GeV)
2	1804	853	66	770	54



- **Event contains 7 jets**
 - ◆ **Signal event with second-highest- S_T**

# jets	S_T (GeV)	$\gamma_1 p_T$ (GeV)	$\gamma_2 p_T$ (GeV)	jet ₁ p_T (GeV)	MET (GeV)
7	1403	275	45	483	63

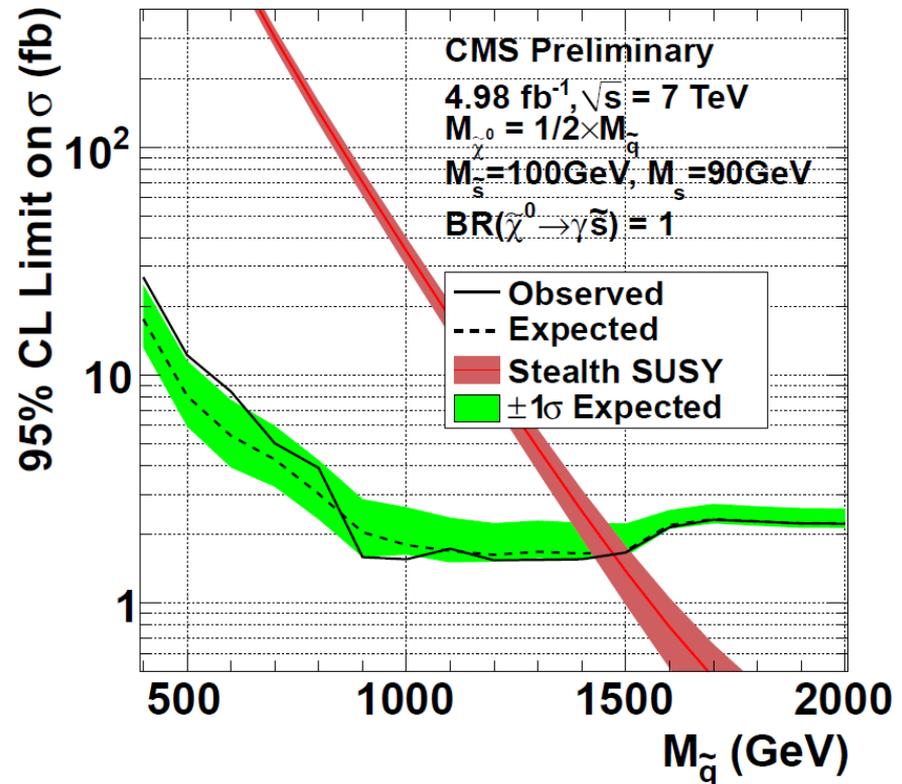




Squark mass limit



- **Set limit using CL_s**
 - ◆ $\pm 1\sigma$ experimental uncertainty band on expected limit
 - ◆ $\pm 1\sigma$ theory uncertainty on predicted cross section
- **Mass exclusion: Intersection of cross section limits and conservative edge of predicted cross section band**
 - ◆ **Observed:** $M_{\tilde{q}} > 1430$ GeV
 - ◆ **Expected:** $M_{\tilde{q}} > 1420$ GeV





Conclusions



- **We conduct new search based on low-MET topologies**
 - ◆ Investigate events with 2 photons, at least 4 jets, $S_T > 700$ GeV
 - ◆ No MET requirement on events
- **Data-driven background estimate from method of S_T scaling**
 - ◆ Data in good agreement with estimate
- **We compute first limits on squark mass in Stealth SUSY framework**
 - ◆ Squark masses below 1430 GeV excluded at 95% CL

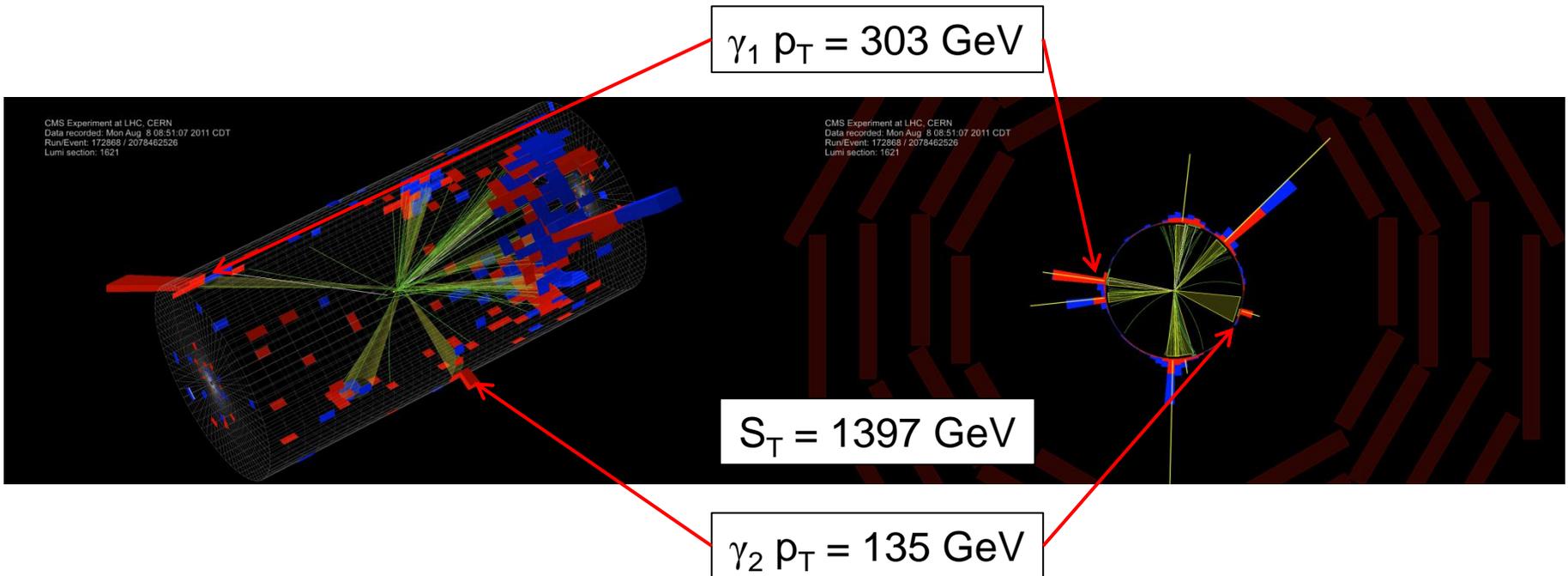


Backup slides



Highest sub-leading photon p_T event

# jets	S_T (GeV)	$\gamma_1 p_T$ (GeV)	$\gamma_2 p_T$ (GeV)	jet ₁ p_T (GeV)	MET (GeV)
4	1397	303	135	554	51





Stealth SUSY kinematics



- **Squark masses range from 400 GeV to 2 TeV**
- **LO cross sections range from 3061 fb to 0.04 fb**
 - ◆ **NLO cross sections range from 4441 fb to 0.15 fb**
- **Signal efficiency typically 38% – 45% for squark masses below 1.5 TeV (less than gluino mass)**
 - ◆ **Efficiency drops to 28% – 32% once gluino production becomes dominant**
 - **Greater jet multiplicity spoils photon isolation**
- **Average jet multiplicity 5 – 6 for squark masses below 1.5 TeV**
 - ◆ **Jet multiplicity 8 – 9 after gluino production becomes dominant**