Search for Supersymmetry with photons at CMS

Dongwook Jang

Carnegie Mellon University

for CMS Collaboration

March 26-30, DIS 2012

Contents

Introduction

- SUSY searches with photons at CMS
  1. Two photons, Missing transverse energy (MET), several jets
  2. One photon, MET, several jets
  3. Above with b-tags (in progress)
  4. Photons with razor variables (in progress)
  5. Stealth SUSY with photons (in progress)
- Only 1 and 2 will be discussed today
  - In General Gauge Mediation (GGM)
  - Reference : CMS PAS (SUS-12-001)

In GGM

LSP : Gravitino
NLSP : Neutralino

Gaugino mixing scenarios

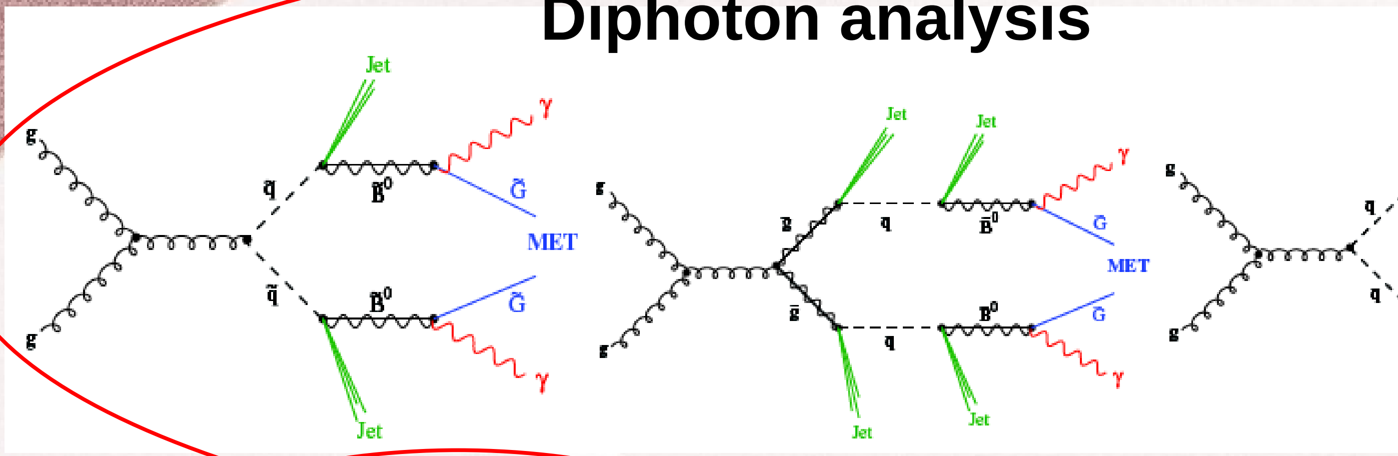
Bino-like neutralino
Production mechanism : gluino pair production
Decay : dominantly a photon
Cross section : gluino mass
Analysis : suitable for Diphoton analysis

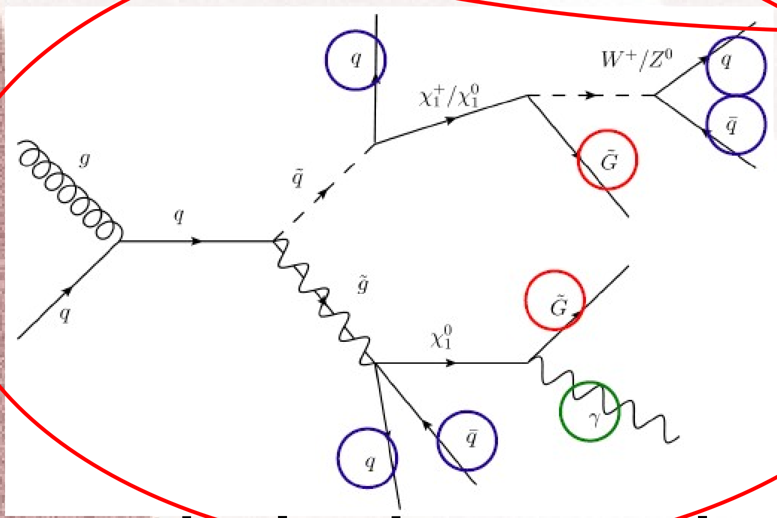
Wino-like neutralino/chargino
Production mechanism : Colored states or Wino pair production
Decay : dominantly a Z/W
Cross section : gluino and wino mass
Analysis : suitable for single photon analysis

Higgsino-like neutralino
Production mechanism : Colored states production
Decay : dominantly a Z
Cross section : gluino and Higgsino mass
Analysis : Not covered yet

Search Strategy

Diphoton analysis





Single Photon analysis

- Photons
- Large MET (gravitino)
- Several Jets

Sample Selections

- Data
  - 4.7 fb^{-1} Collected in 2011 at 7 TeV
  - good runs
- Triggers
  - Two photons with Et > 36 and Et > 22, respectively
  - One photon with Et > 70 and HT > 400
  - All photons are required to have H/E < 0.15 and $\sigma_{i\eta i\eta}$ < 0.014
  - Loose isolations are applied for both calorimeter and tracker

•H/E : fraction of Hadronic energy over EM energy
•$\sigma_{i\eta i\eta}$: shower shape variable

Particle Identification

Fake photons

- Same as photons but
- $\sigma_{i\eta i\eta} > 0.011$
- Isocombined > 6 GeV

Electrons

- Same as photons but
- Have pixel hits

Jets

- Cleaning cuts in backup slides

Photons

- In Barrel
- H/E < 0.05
- $\sigma_{i\eta i\eta} < 0.011$
- R9 < 1.0
- No pixel hits
- Isocombined < 6 GeV

Event Selection

Primary Vertex

- Requiring at least one primary vertex
- Not fake, Ndof > 4, |z| < 24 cm, |rho| < 2 cm

Diphoton analysis selection

- Et(1) > 40 GeV & Et(2) > 25 GeV satisfying photon ID
- DR(1,2) > 0.6 for two photons
- Dphi(1,2) > 0.05
- Reconfirm trigger condition with tighter requirement

Single photon analysis selection

- Et > 80 GeV satisfying photon ID
- Reconfirm trigger condition with tighter requirement
- Njets >= 2 or 3

Photon Efficiency

- Assumption: EM responses in detector for electrons and photons are similar
- Measure electron efficiency from the Tag-Probe method using Z->ee sample
- Extract Data/MC scale factor from electron
- Multiply photon efficiency from MC to get photon efficiency for data

$$\epsilon_{\gamma}^{Data} = \epsilon_{\gamma}^{MC} \frac{\epsilon_{e}^{Data}}{\epsilon_{e}^{MC}} \qquad \frac{\epsilon_{e}^{Data}}{\epsilon_{e}^{MC}} = 0.99 \pm 0.04$$

PU correction on Isolation & Cut Optimization

- Measure effective area(A_{eff}) for Ecal and Hcal separately
- Subtract PU contributions from Isolation

$$Iso_{corr} = Iso_{raw} - A_{eff} \times \rho$$

- Optimize cuts based on S/√(B) resulted in 6 GeV
- Put the upper limit on isolation for control sample to not include outliers

Fake rate

- Electrons without pixel matches can be identified as photons
- Select ee and eγ samples falling into the invariant mass between 70 and 110 GeV
- Fit the invariant mass distributions with crystal-ball function for signal and error function+exponential for background
- Obtain pT dependent e->γ fake rate by comparing siganl/background yields from fit

Diphoton: Background Estimation

- Background with real MET(called EW)
  - Wγ (W->eν) where an electron fakes a photon
  - Use data-driven method
  - Measure e->γ fake rate using Z->ee
  - Apply fake rate to electron from eγ selection
- Background without real MET (called QCD)
  - QCD: γγ, γj,jj where jets fake photons
  - Use data-driven method
  - Select control samples where no real MET is expected
  - Take MET shape from the control samples and normalize the shape to candidate shape (MET < 20 GeV)

Diphoton: Electroweak Background

- Real MET
- Main contribution from Wγ (W->eν) where electron fakes photon
- Take MET distribution from eγ sample
- Apply fake rate with the formula below

$$N_{\gamma\gamma}^{obs} = f_{e\to\gamma} N_{W\gamma}^{true}$$

$$N_{e\gamma}^{obs} = (1-f_{e\to\gamma}) N_{W\gamma}^{true}$$

$$N_{\gamma\gamma}^{obs} = \frac{f_{e\to\gamma}}{(1-f_{e\to\gamma})} N_{e\gamma}^{obs}$$

Diphoton: QCD background

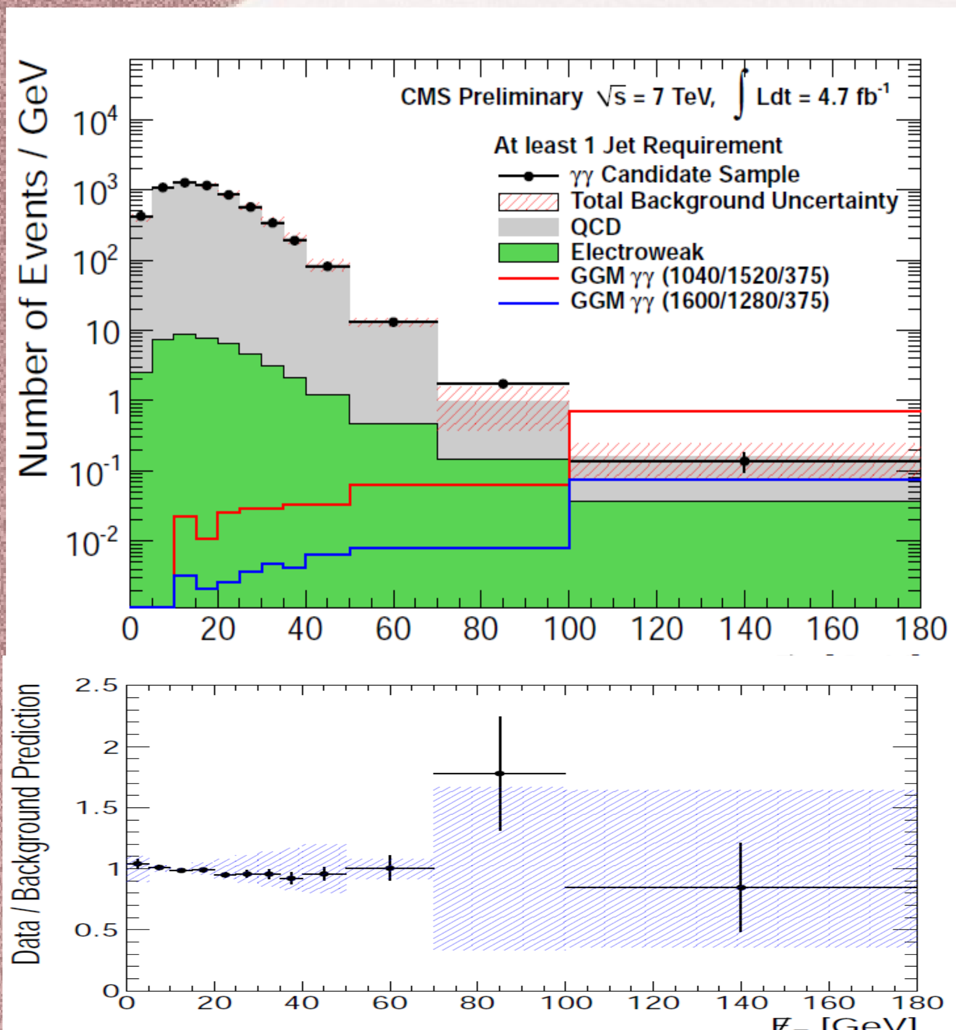
- Fake MET
- Mostly QCD
- Two control samples
  - Select Z->ee sample by subtracting sideband to eliminate possible contributions from ttbar (called ee)
  - Select non-isolated photons (called ff)
- Take MET shape
  - JetPt (known as DiEMpt previously) reweighting is applied to the samples to simulate the hadronic recoils
  - Normalize the shape to $\gamma\gamma$ sample where MET < 20 GeV
- Uncertainty is determined by the estimation difference between ee and ff samples

Single photon: Background Estimation

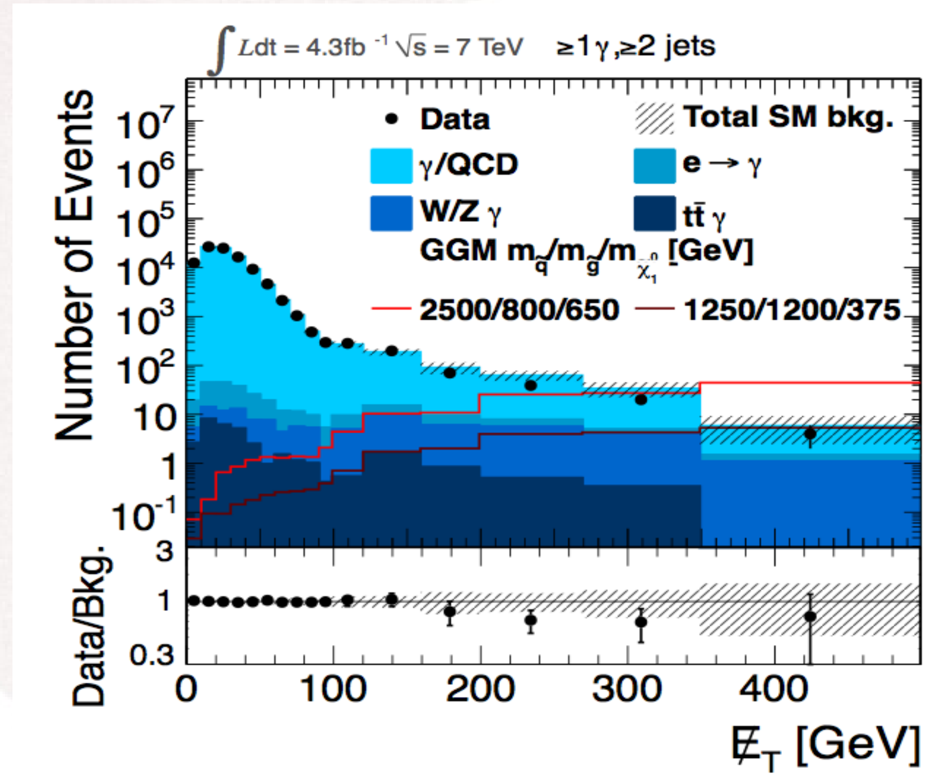
- Background with real MET (EW)
  - Small background; mostly coming from W and ttbar processes
  - Estimated using the same procedure as the diphoton analysis
- Background without real MET (QCD)
  - Dominant background; mostly coming from QCD jets
  - Estimated using data-driven method by reweighting the fake object pT spectrum to the photon pT spectrum in MET < 100 GeV
  - Uncertainty is determined by reweighting procedure extrapolating low to high pT bins in pT spectrum, as well as the different jet multiplicities
- ISR/FSR
  - Very small background; estimated using MC

Results

Diphoton analysis MET distribution



Single photon analysis MET distribution



Ref: SUS-12-001

Signal MC

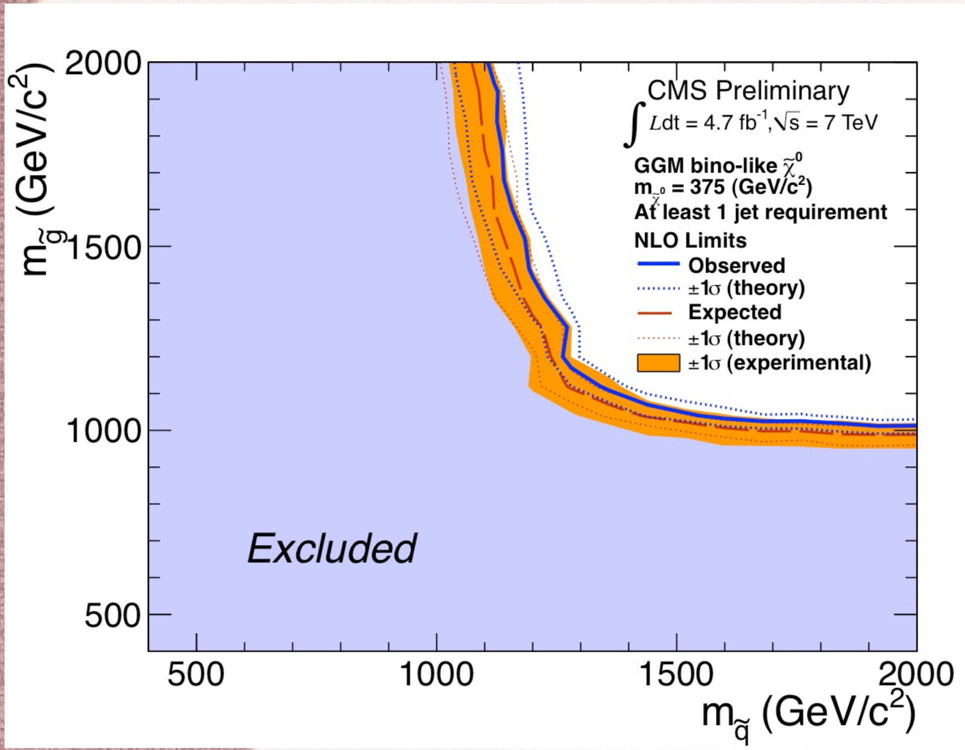
- Pythia event generator
- CMS fast detector simulation
- Fix Bino-like neutralino mass at 375 GeV
  - Squark and gluino masses run from 400 to 2000 with 80 GeV binning
- Fix Wino-like neutralino mass at 375 GeV
  - Squark and gluino masses run from 400 to 2000 with 80 GeV binning
- Fix squark mass at 2500 GeV
  - gluino mass from 400 to 2000 with 80 GeV binning
  - Neutralino mass from 150 to 1050 with 100 GeV binning

Limit settings

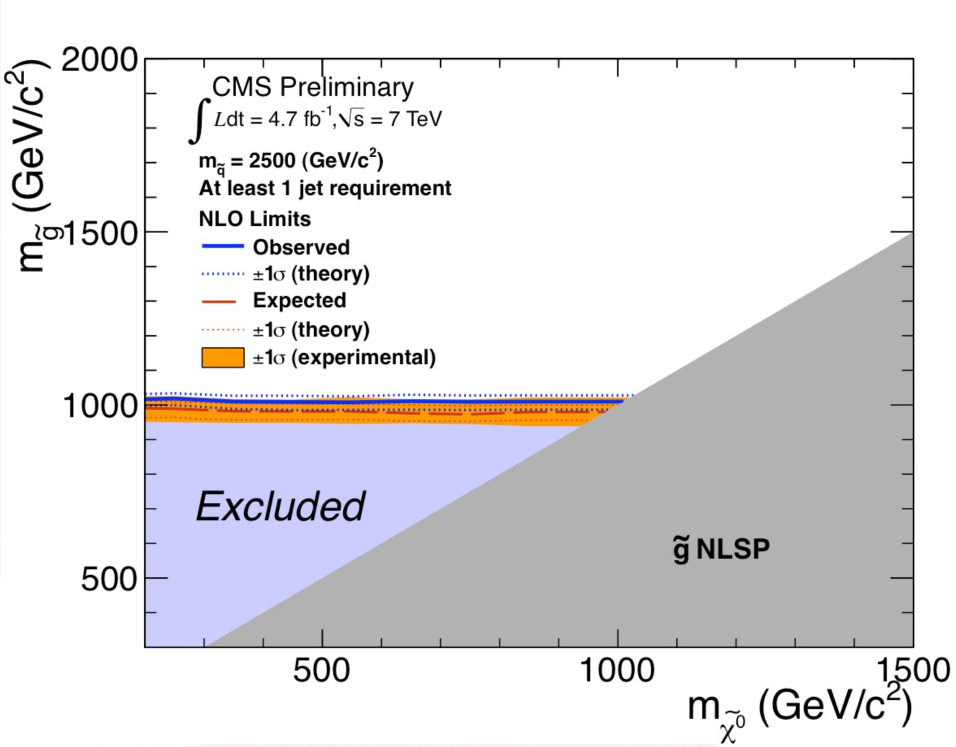
- Observed no excess in data -> setting limits on cross sections
- Simplified model scans in GGM as described in the previous slides
- NLO cross sections
- Frequentest CLs methods
- Exclusions on squark/gluino masses as well as gluino/neutralino masses
- UED interpretations for the diphoton case

Diphoton exclusions

$m_{gluino} – m_{squark}$ plane



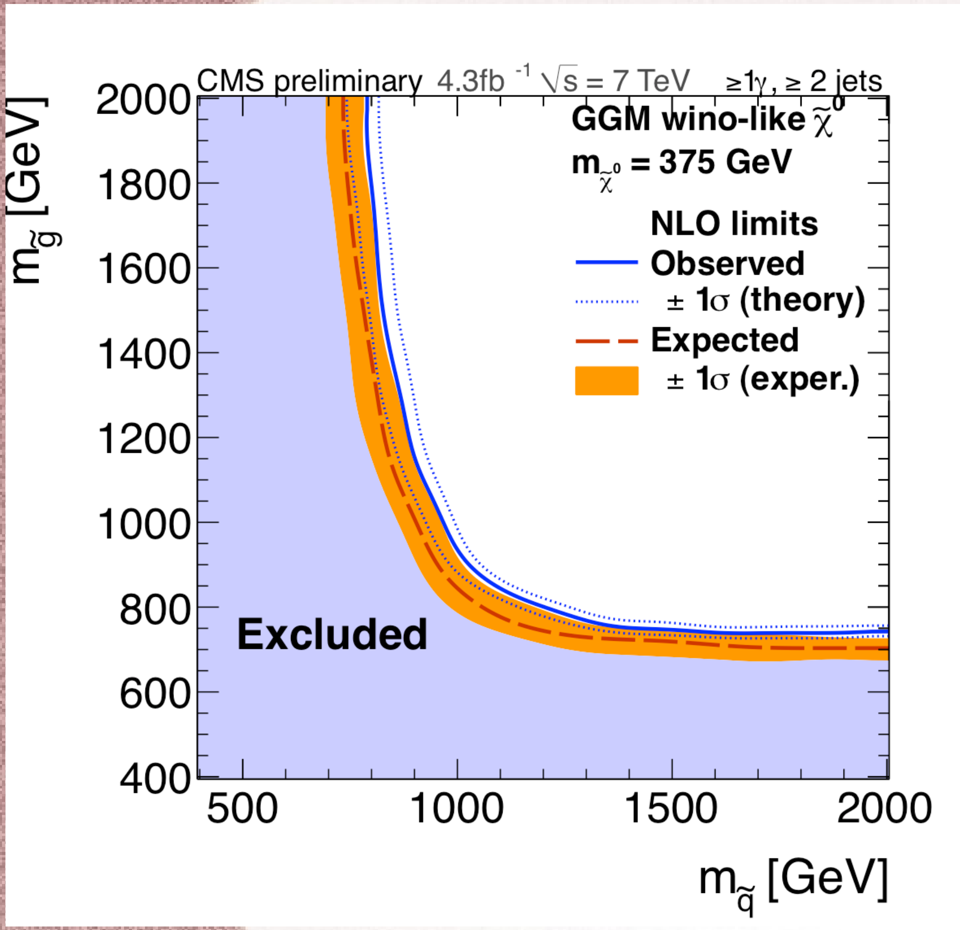
$m_{gluino} – m_{neutralino}$ plane



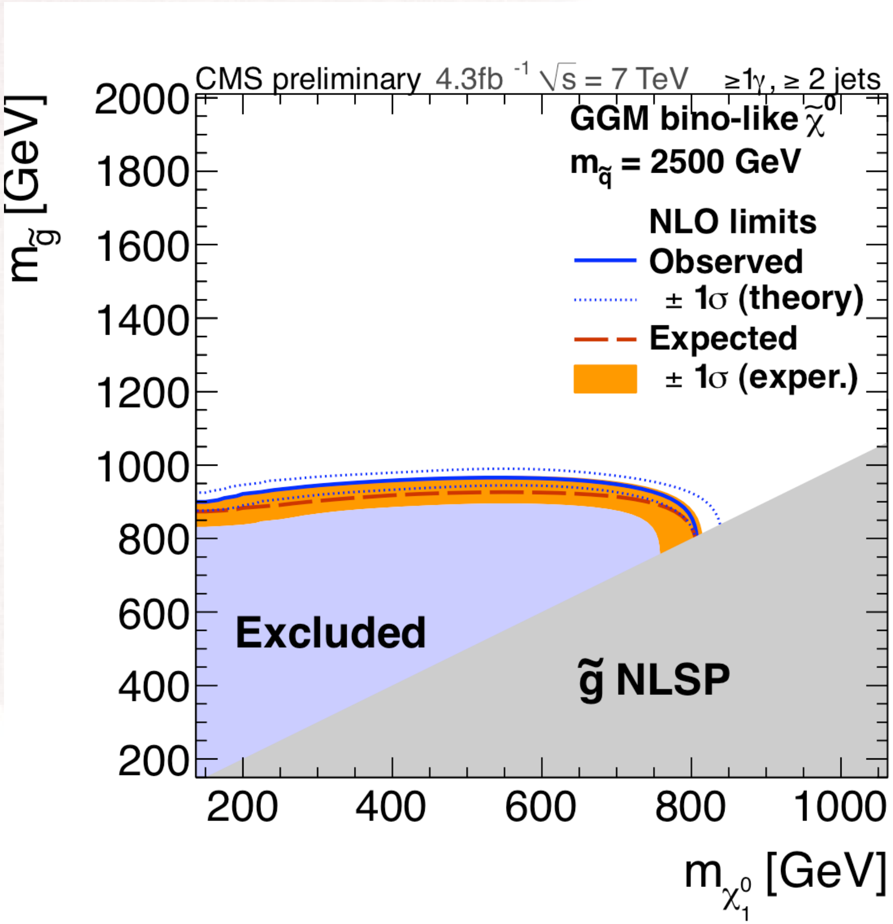
Ref: SUS-12-001

Single photon exclusions

$m_{gluino} - m_{squark}$ plane

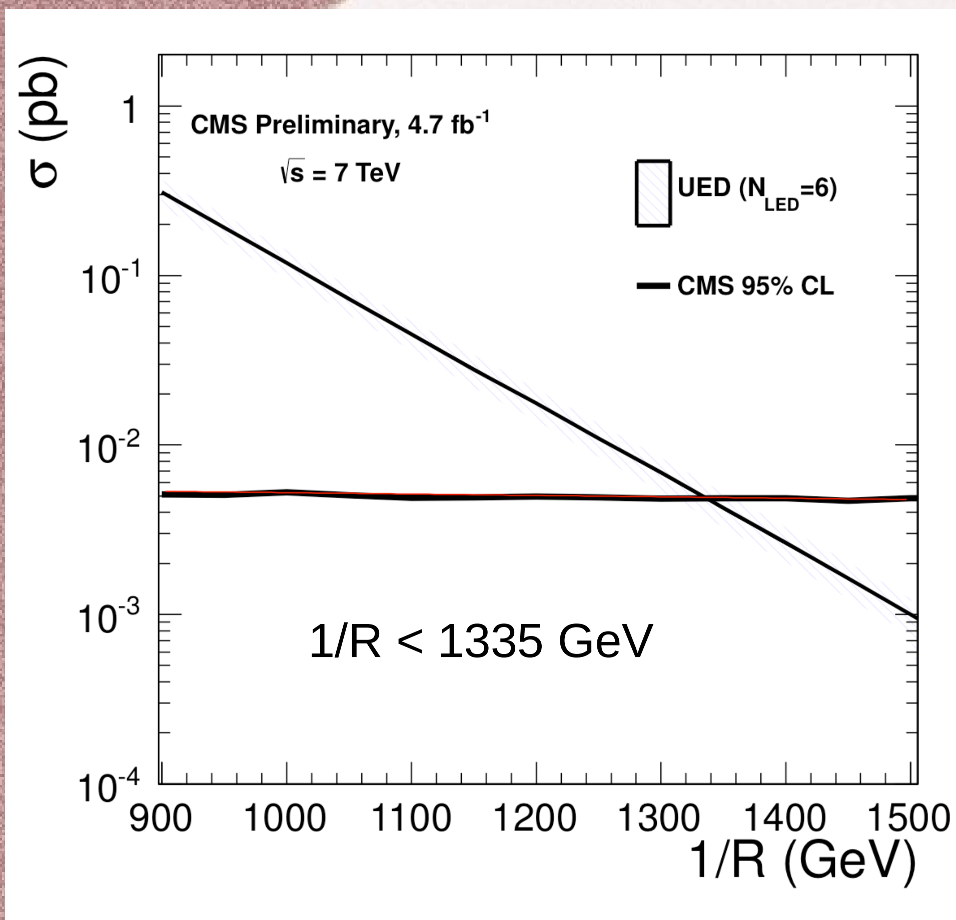


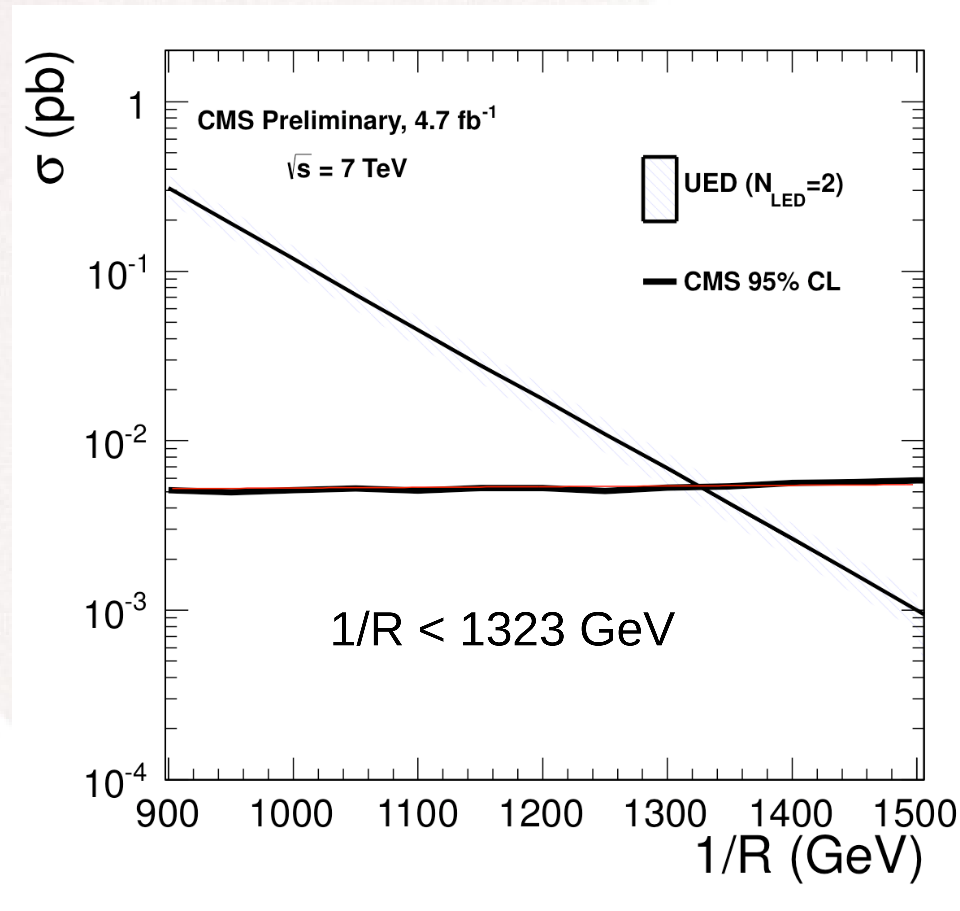
$m_{gluino} - m_{neutralino}$ plane



Ref: SUS-12-001

UED interpretation for diphoton case





R : the size of compactification
N : the number of dimensions

Ref: SUS-12-001

Summary

- No excess in data from both diphoton and single photon analysis
- Set 95% CL upper limit on cross section: 0.01 pb for bino-like scenario and 0.1 pb for wino-like scenario
- Squark amd gluino masses are excluded less than 1 TeV
- UED interpretation: 1/R < 1323(1335) GeV for NLEDs = 2 (6)

Backup Slides

Jet Cleaning

- AK5 L1FastL2L3 corrected PFJet
- Pt > 30 GeV/c
- |Eta| < 2.6
- Neutral Hadron Fraction < 0.99
- Neutral EM Fraction < 0.99
- Number of Constituents > 1
- Charged Hadron Fraction > 0
- Charged EM Fraction < 0.99
- Charged Multiplicity > 0
- dR between photons and jets >= 0.5 if require 1+jet
- Jet cleaning cone size dR = 0.5