Search for Supersymmetry in Events with Photons and Missing Transverse Energy

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On behalf of CMS Collaboration

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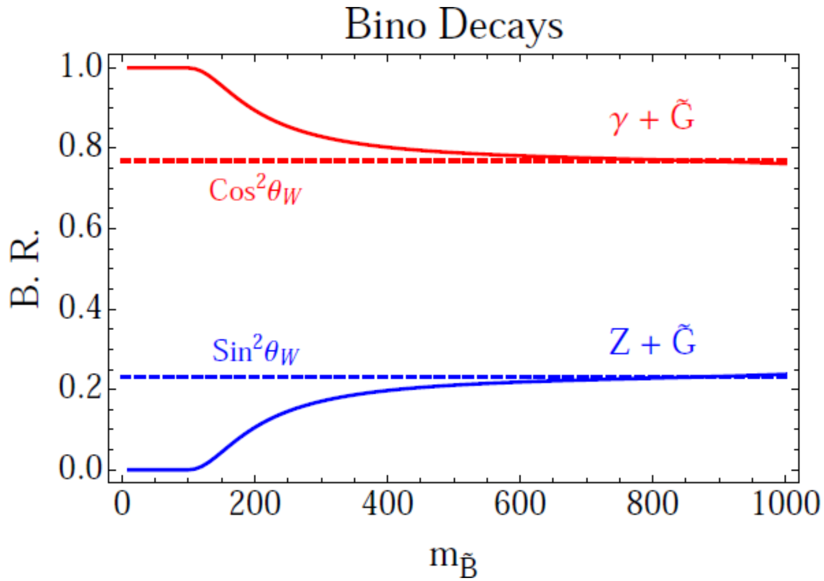
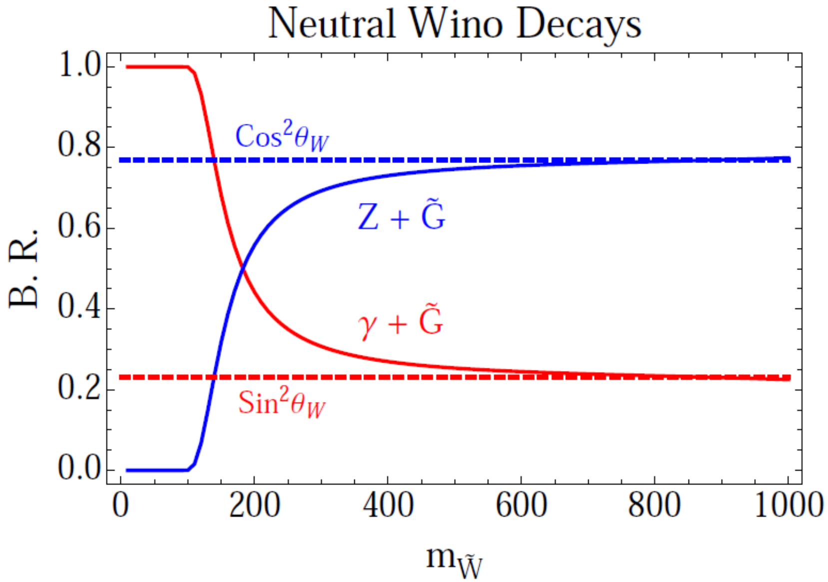
SUSY Model

- Gauge Mediated Supersymmetry Breaking (GMSB)
- Gravitino is the lightest SUSY particle (LSP) in GMSB
- Consider Neutralino is the next-to-lightest SUSY particle (NLSP)
- Neutralino mass eigenstates are mixtures of Bino, Wino, and Higgsinos
- If R-parity is conserved, SUSY particles are produced in pair





J. Ruderman, D. Shih
ArXiv:1103.6083v1

Analysis Channels

Analysis	Photon	Jet	Bkg.	Bkg. Estimation Method
Single Photon	Et > 80 GeV $\|\eta\| < 1.44$	Et > 30 GeV >= 2 Jets HT > 450 GeV $\|\eta\| < 2.6$	QCD EWK $W/Z/t\bar{t}+\gamma$	Data-driven + MC
Di-Photon	Et > 40, 25 GeV $\|\eta\| < 1.44$	Et > 30 GeV $\|\eta\| < 2.6$	QCD EWK	Data-driven

Analysis at CMS: CMS PAS SUS-12-001

Identifications and Event Selections

Di-Photon Analysis

Photons:

leading photon Et > 40 GeV
trailing photon Et > 25 GeV
$|\eta| < 1.44$

Electrons:

Identical to photons' ID
but require PixelSeed

Fake Photons:

Identical to photons' ID
but reverse combined Isolation
or $\sigma_{i\eta i\eta}$

Jets:

particle flow jets
Et > 30 GeV
$|\eta| < 2.6$

$\gamma\gamma$ Sample:

candidate sample

$e\gamma$ Sample:

EWK background estimation

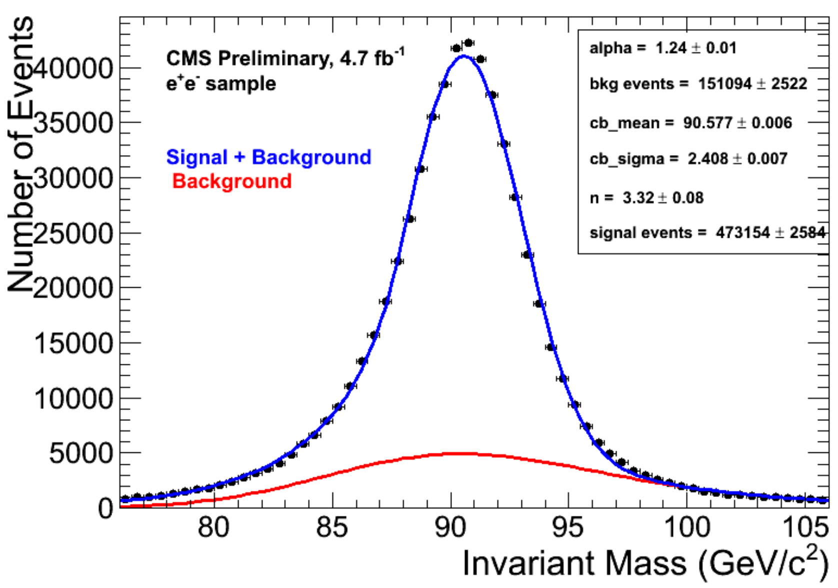
ff and ee samples:

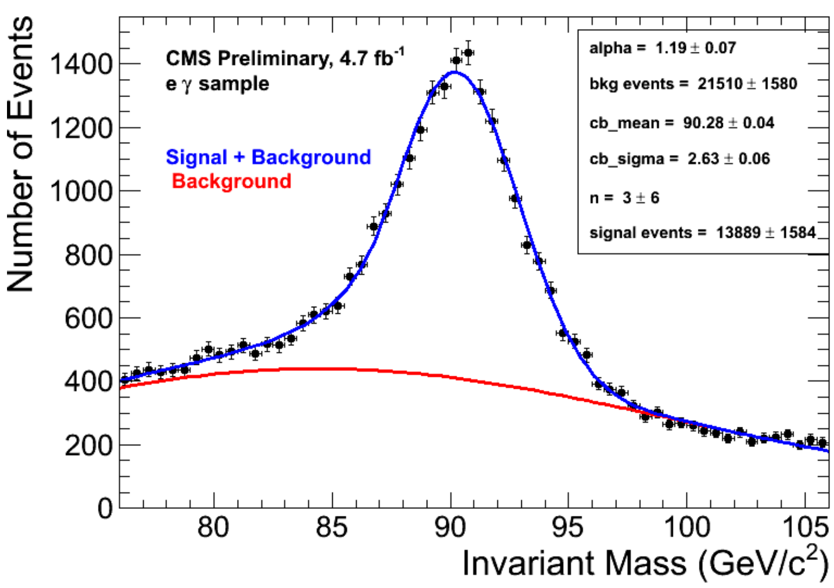
QCD background estimation control samples

Estimation of MET Background (Electroweak)

Di-Photon Analysis

- Fit Z peak in ee and $e\gamma$ invariant mass spectra to get the numbers of events, respectively.
- $\dfrac{N_{e\gamma}(Z \to ee)}{N_{ee}(Z \to ee)} = \dfrac{2f_{e\to\gamma}}{(1-f_{e\to\gamma})}$ $\quad f_{e\to\gamma}$: $0.015 +/- 0.002(stat.) +/- 0.005(syst.)$
- Scale the MET distribution of $e\gamma$ sample by $\dfrac{f_{e\to\gamma}}{(1-f_{e\to\gamma})}$





Estimation of MET Background (QCD)

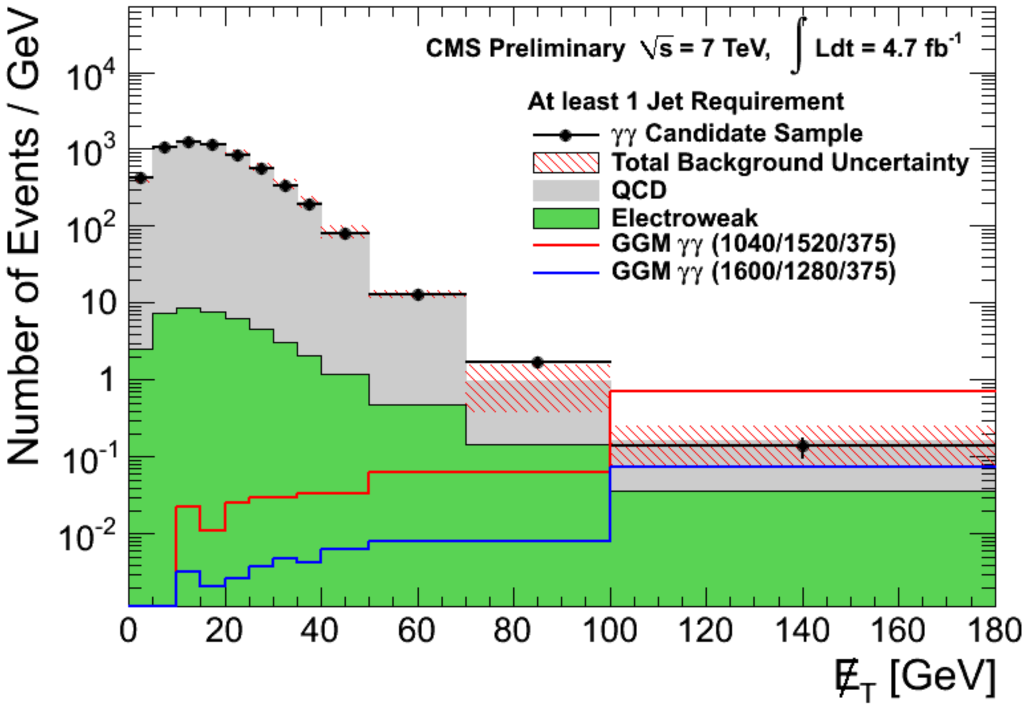
Di-Photon Analysis

- Use both control samples to estimate QCD MET distribution.
- If there is no TRUE MET in the event, the resolution of hadronic activity in the event will dominate the MET.
- Take the di-Jet Pt spectrum from candidate sample as a measure of hadronic activity in the event.
- Reweight the shape of MET distribution of control samples by using the di-Jet Pt ratio of candidate sample and control samples.
- Normalize the reweighted MET distribution to low MET region (below 20 GeV) of candidate events.

Single Photon Analysis

- The strategy is very similar to Di-photon's
- Reweight the control sample (fake photon) to estimate QCD background
- Apply $f_{e\to\gamma}$ to the control sample (electron) to estimate background $e\to\gamma$
- ISR/FSR $(W/Z/t\bar{t})$ contributions are determined directly from MC

MET Distribution (Di-Photon)

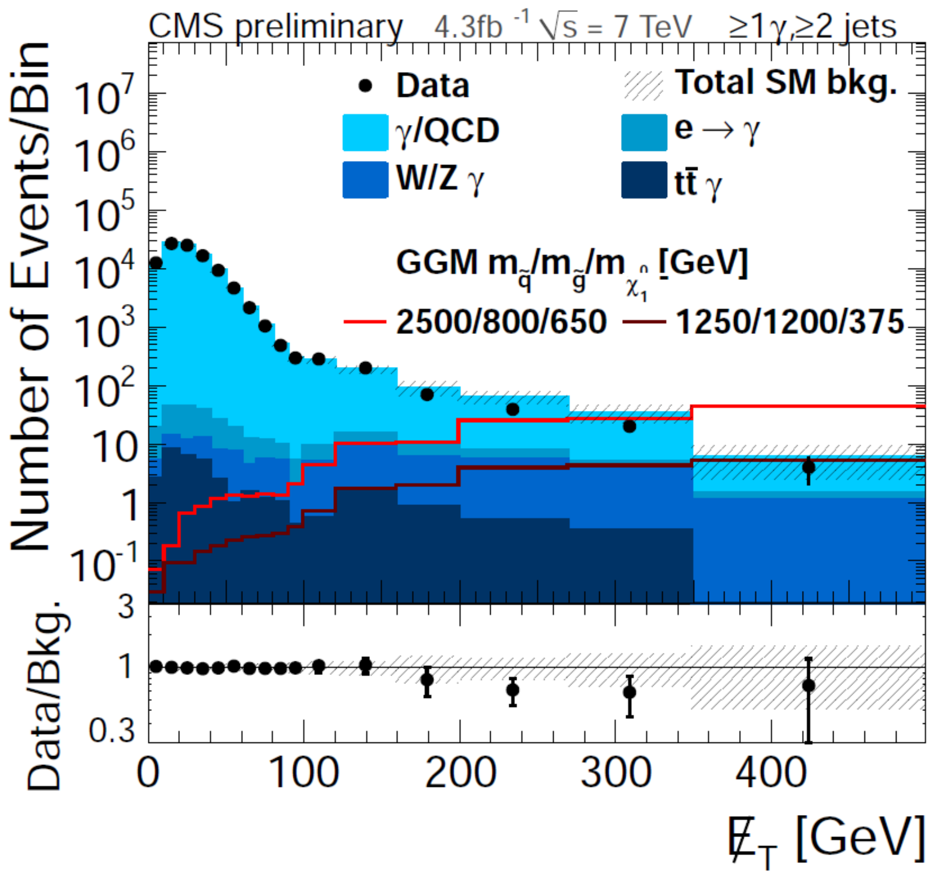


Number of events with MET > 100 GeV

Type	Events	scal. error	norm. error
$\gamma\gamma$ candidates	11		
ff QCD background	10.1 ± 4.2	± 0.3	± 0.03
ee QCD background	14.7 ± 3.1	± 0.1	± 0.03
EWK background	2.9 ± 1.0	± 0.0	± 0.9
Total background (ff)	13.0 ± 4.3		

- No excess beyond Standard Model

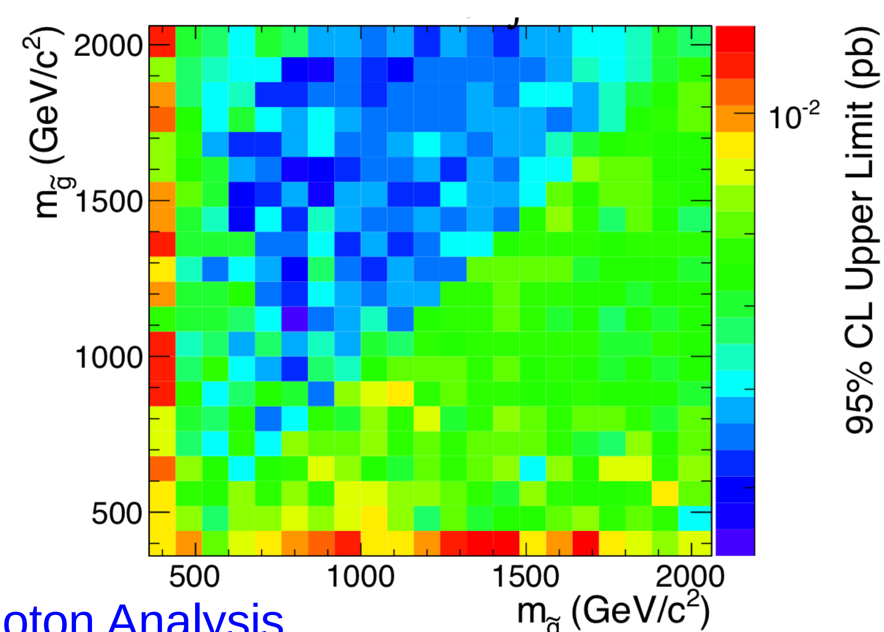
MET Distribution (Single Photon)

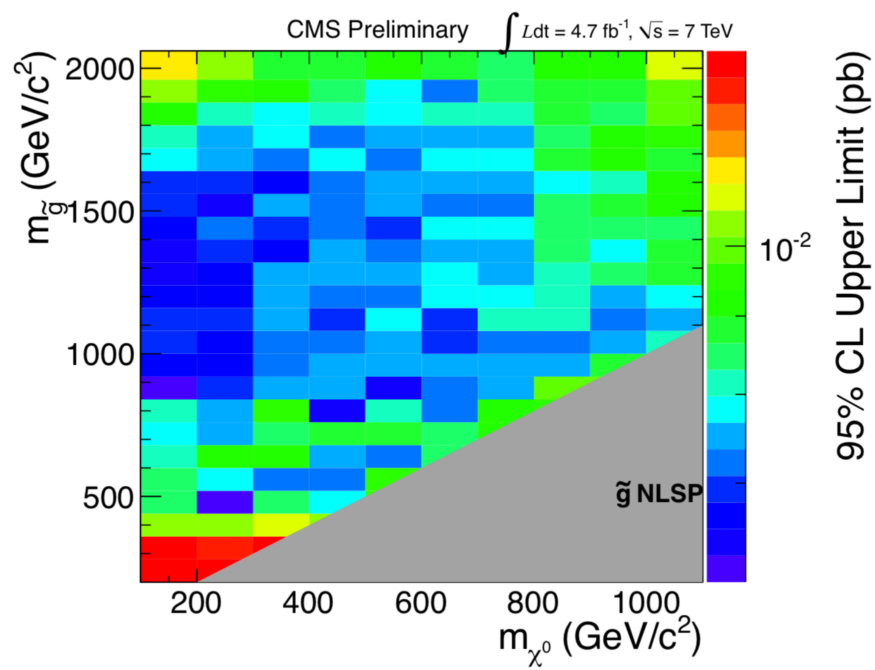


$\geq 1\gamma, \geq 2$ jets	$E_T^{miss} \geq 100$ GeV	(stat.)	(syst.)	$E_T^{miss} \geq 200$ GeV	(stat.)	(syst.)	$E_T^{miss} \geq 350$ GeV	(stat.)	(syst.)
QCD (from data)	607.7	± 46.7	± 54.0	90.7	± 16.4	± 9.9	6.8	± 4.1	± 0.8
$e \rightarrow \gamma$ (from data)	17.2	± 0.3	± 7.2	3.5	± 0.2	± 1.5	0.4	± 0.01	± 0.2
FSR/ISR(W, Z)	27.6	± 3.2	± 27.6	10.4	± 2.0	± 10.4	1.6	± 0.8	± 1.6
FSR/ISR$(t\bar{t})$	3.8	± 0.9	± 3.8	0.8	± 0.4	± 0.8	< 0.01	< 0.01	< 0.01
total SM estimate	656.4	± 46.9	± 92.7	105.5	± 16.5	± 22.6	8.7	± 4.2	± 2.5
Data	615			63			4		

Systematics	Uncertainty [%]
Integrated luminosity	4.5
Pile-up study	2.4
Photon Data/MC scale	2.6
Photon/Electron ID	0.5
Jet energy scale	2
Renormalization scale	4 - 28
PDF error on cross section	4 - 66
PDF error on acceptance	0.1 - 9

$$\frac{\epsilon_{\gamma}^{Data}}{\epsilon_{\gamma}^{MC}} = \frac{\epsilon_{e}^{Data}}{\epsilon_{e}^{MC}}$$

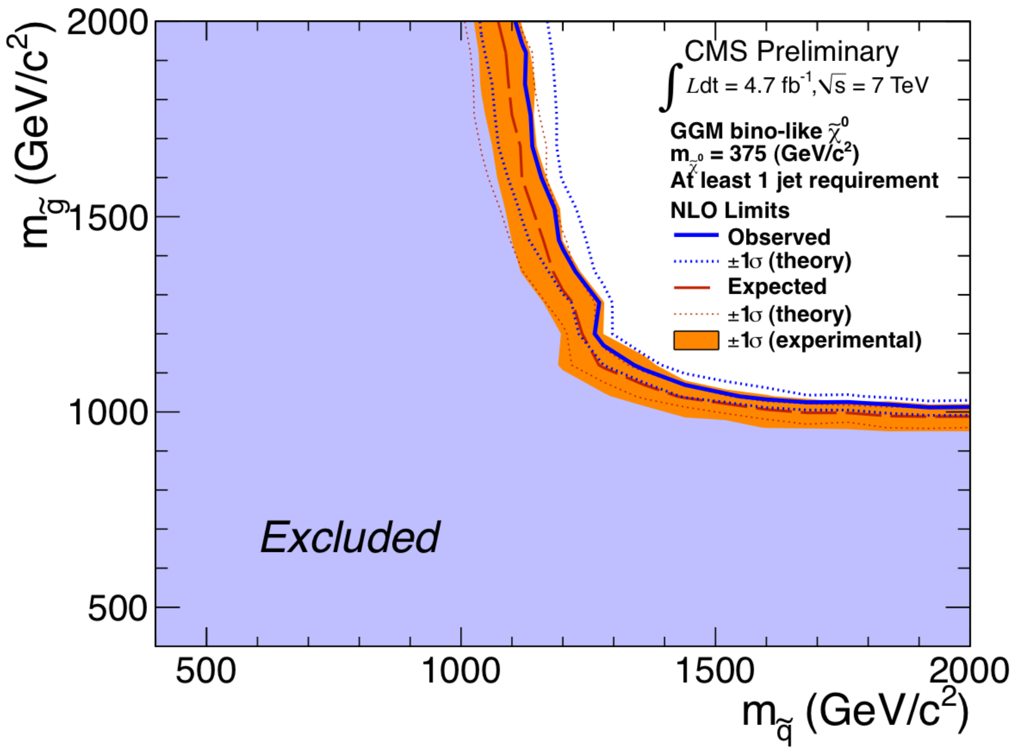


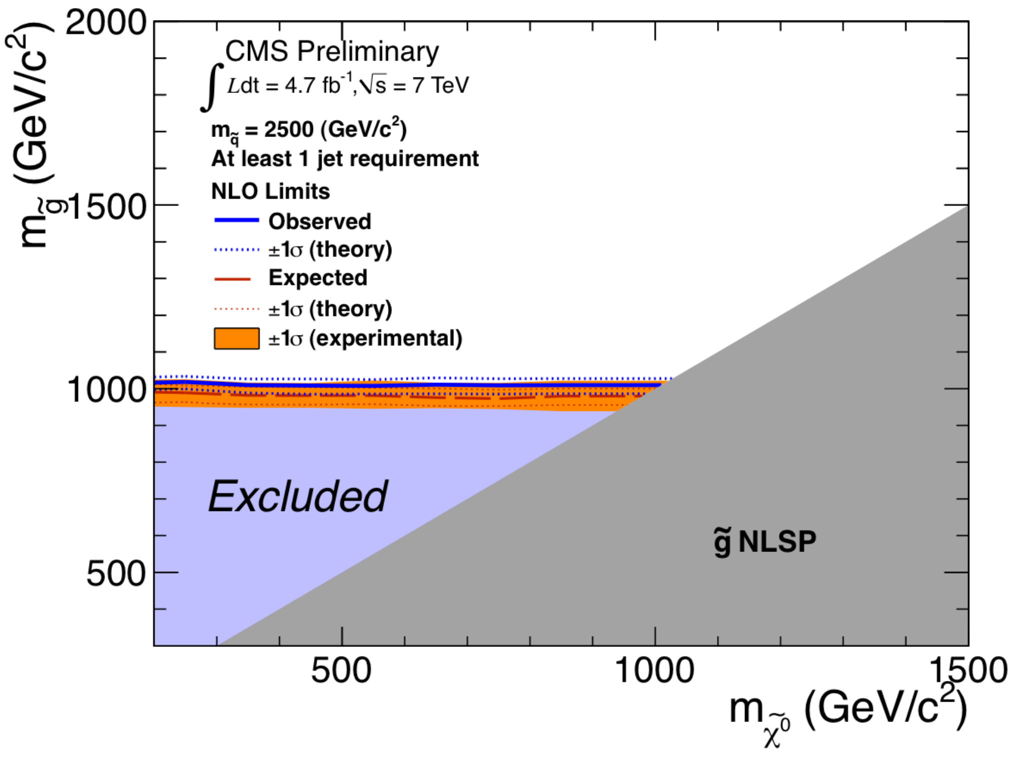


Di-Photon Analysis

Result and Interpretations

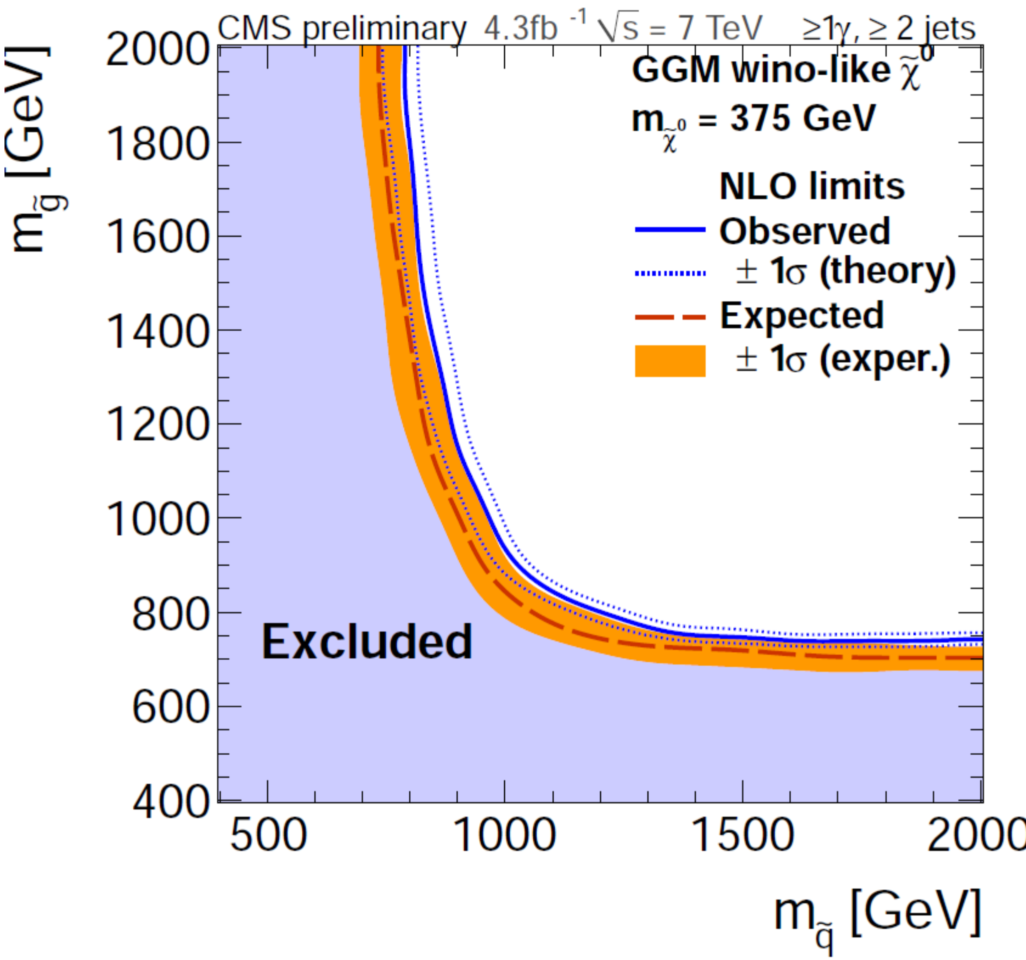
Di-Photon Analysis

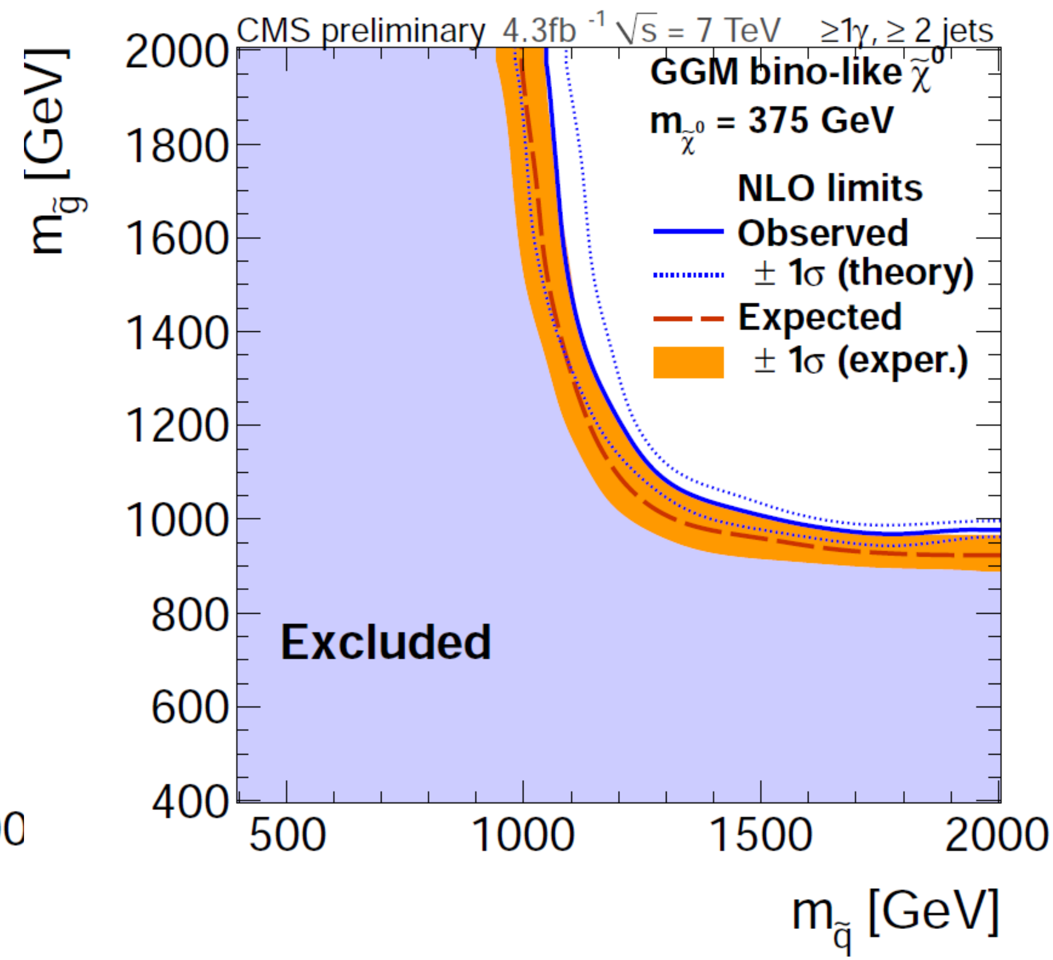




Result and Interpretations

Single Analysis





Summary

- We have completed searches for GMSB SUSY with single and di-photon final state using all 2011 data.
- Data-driven methods are used to estimate dominate backgrounds.
- We observe no excess beyond Stand Model.
- We set the 95% CL upper limit on cross sections and exclude gluino and squark masses below

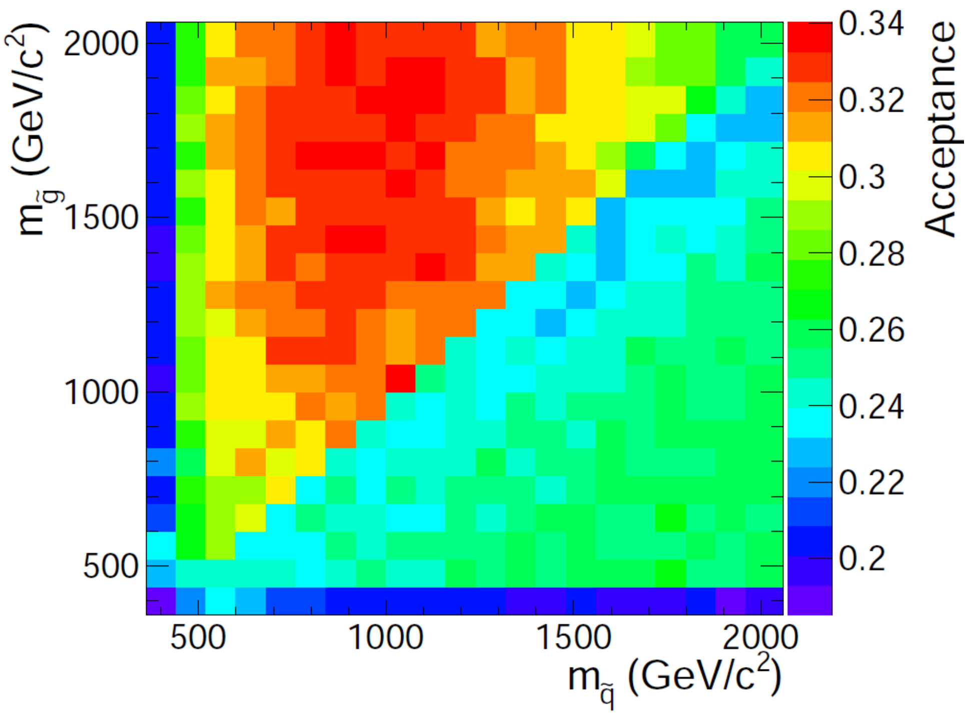
~1TeV (bino-like neutralino)

~750 GeV (wino-like neutralino).

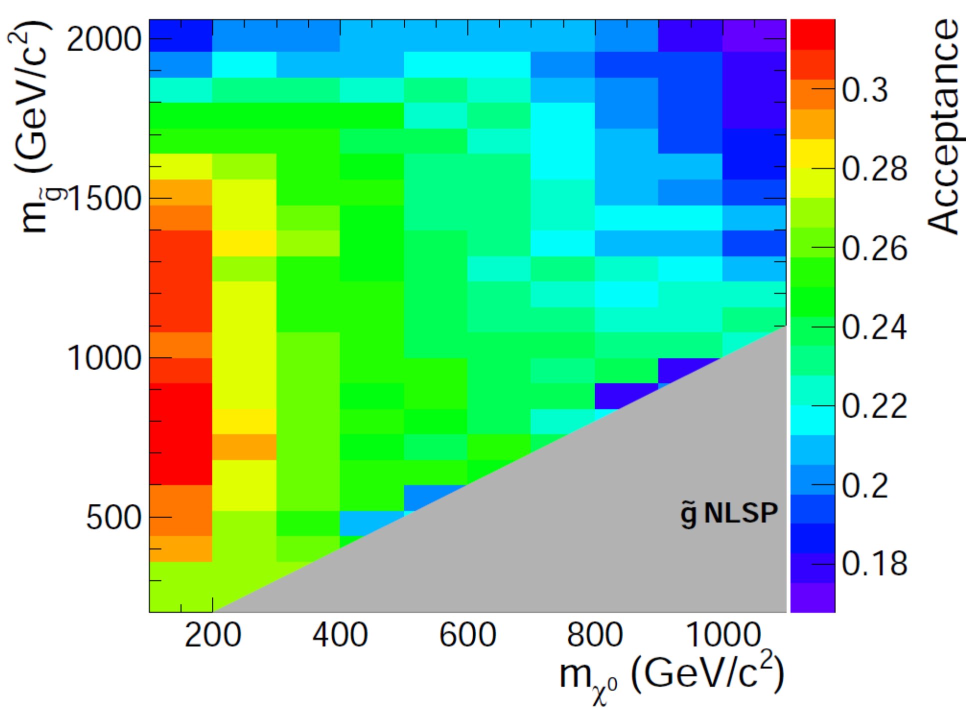
Backup Slides

Acceptance times Efficiency

Di-Photon Analysis



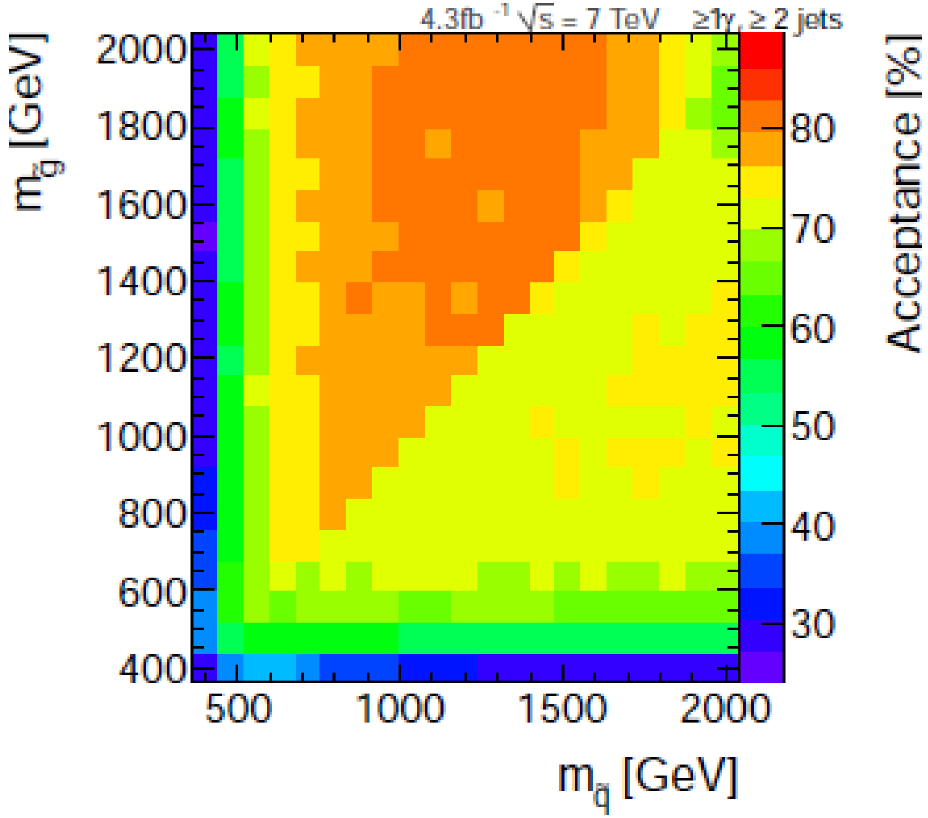
Bino-like neutralino



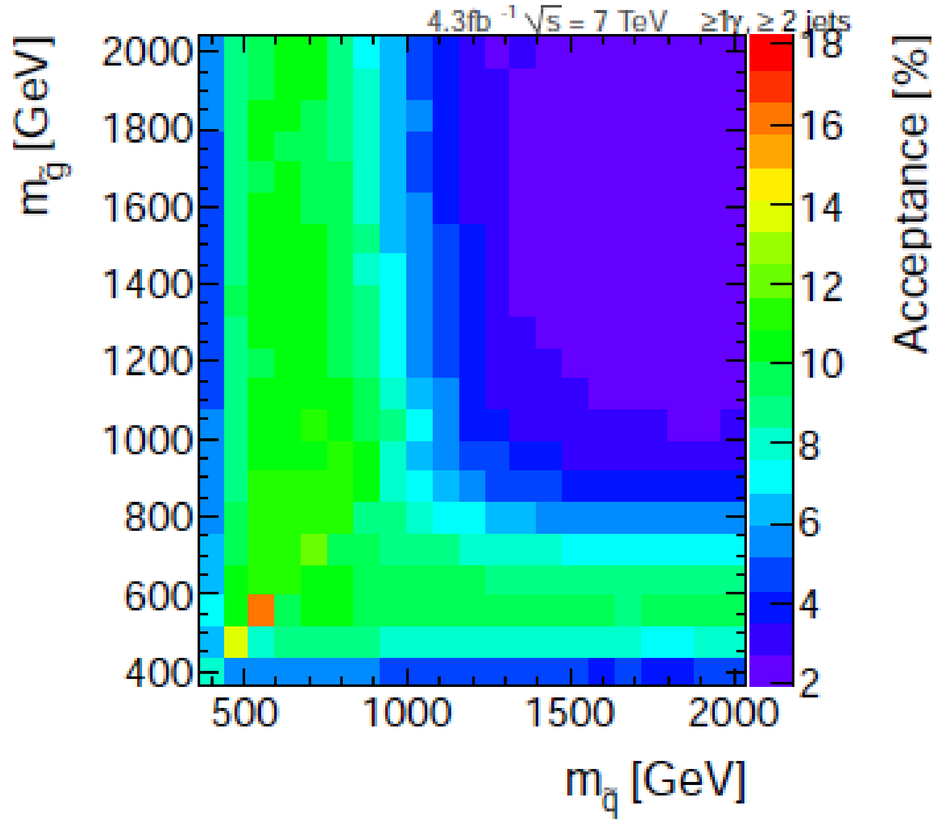
Bino-like neutralino

Acceptance times Efficiency

Single Photon Analysis

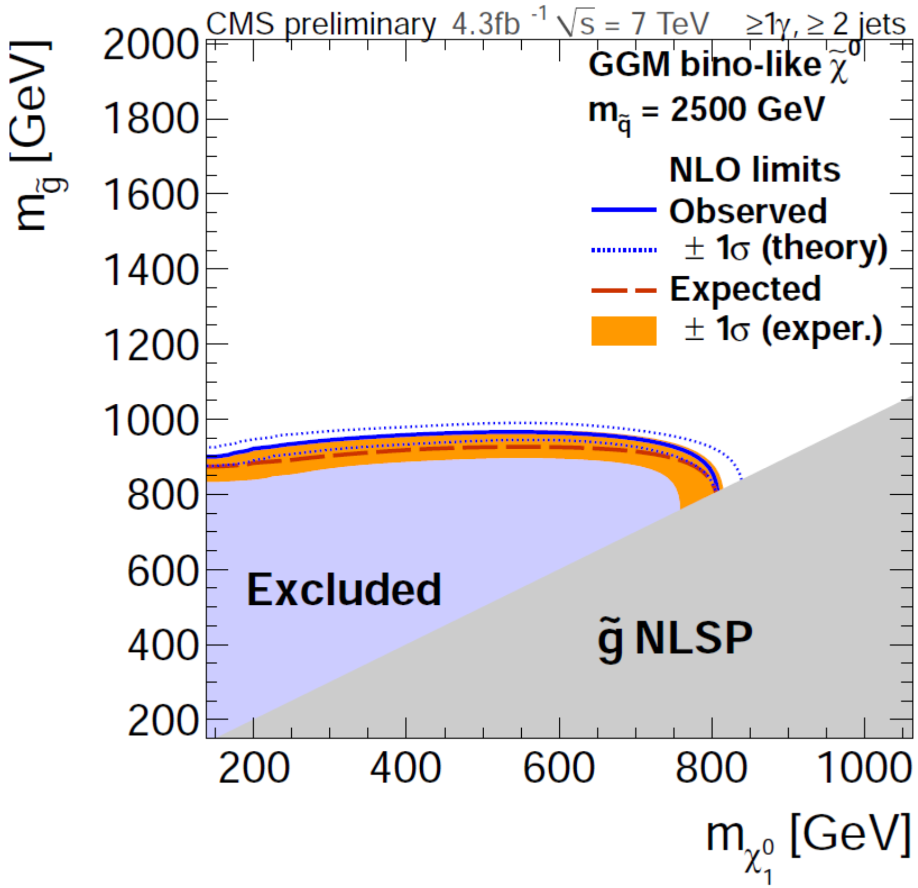


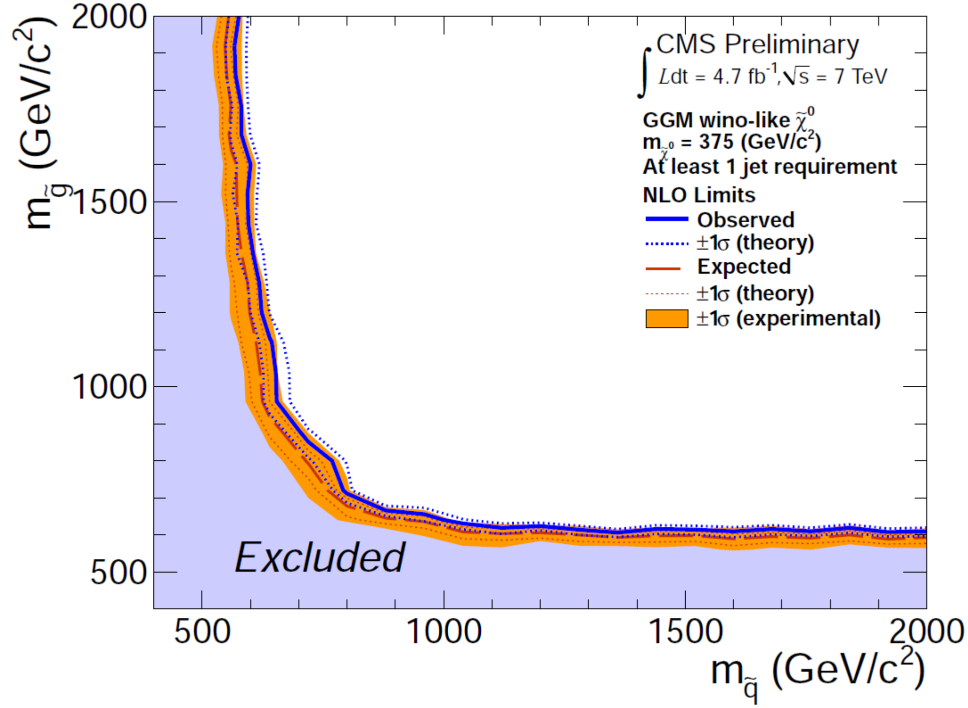
Bino-like neutralino



Wino-like neutralino

Result and Interpretations





Identifications

- Photons :
  - In barrel region (|Eta| < 1.4442)
  - leading photon Et > 40 GeV, trailing photon Et > 25 GeV
  - combined Isolation (DR03 cone) < 6 GeV
  - H/E < 0.05
  - $\sigma_{i\eta i\eta} < 0.011$
  - No PixelSeed
  - r9 < 1.0
- Fake Photons:
  - Identical to photons but reverse combined Isolation (6 < Combined Isolation < 20 GeV) OR
  - $0.011 < \sigma_{i\eta i\eta} < 0.014$

Single Photon case:
6 < Combined Isolation < min (30, 0.3*Pt)

- Electrons :
  - Identical to photons but requiring PixelSeed

Identifications and Event Selections

- Jets:
  - 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

- Primary Vertex Selection:

  Requiring at least one primary vertex
  - Not fake
  - Ndof > 4
  - fabs(z) < 24 cm
  - fabs(rho) < 2 cm

- Selected EM objects must be separated by dR > 0.6
- For no jet requirement case, dPhi between selected EM objects > 0.05
- Apply invariant mass 81- 101 GeV cut to ee sample

ATLAS Result